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# CARNEGIE INSTITUTION OF WASHINGTON

YEAR BOOK No. 41

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CARNEGIE INSTITUTION OF WASHINGTON  
WASHINGTON, D. C.

1942



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# PRESIDENT AND TRUSTEES

## PRESIDENT

VANNEVAR BUSH

## BOARD OF TRUSTEES

W. CAMERON FORBES, *Chairman*

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## STANDING COMMITTEES FOR THE YEAR 1943

### *Committee on Astronomy*

HERBERT HOOVER, *Chairman*

WALTER S. GIFFORD  
ROSWELL MILLER

SEELEY G. MUDD  
ELIHU ROOT, JR.

### *Committee on Terrestrial Sciences*

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JAMES F. BELL

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ALFRED L. LOOMIS

### *Committee on Historical Research*

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ROBERT WOODS BLISS  
RICHARD P. STRONG

CHARLES P. TAFT  
JAMES W. WADSWORTH

## FORMER PRESIDENTS AND TRUSTEES

### PRESIDENTS

DANIEL COIT GILMAN, 1902-04                      ROBERT SIMPSON WOODWARD, 1904-20  
JOHN CAMPBELL MERRIAM, *President* 1921-38; *President Emeritus* 1939-

### TRUSTEES

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WILLIAM W. CAMPBELL	1929-38	WILLIAM W. MORROW	1902-29
JOHN J. CARTY	1916-32	WILLIAM CHURCH OSBORN	1927-34
WHITEFOORD R. COLE	1925-34	JAMES PARMELEE	1917-31
CLEVELAND H. DODGE	1903-23	WM. BARCLAY PARSONS	1907-32
WILLIAM E. DODGE	1902-03	STEWART PATON	1916-42
CHARLES P. FENNER	1914-24	GEORGE W. PEPPER	1914-19
SIMON FLEXNER	1910-14	HENRY S. PRITCHETT	1906-36
WILLIAM N. FREW	1902-15	ELIHU ROOT	1902-37
LYMAN J. GAGE	1902-12	JULIUS ROSENWALD	1929-31
CASS GILBERT	1924-34	MARTIN A. RYERSON	1908-28
FREDERICK H. GILLETT	1924-35	THEOBALD SMITH	1914-34
DANIEL C. GILMAN	1902-08	JOHN C. SPOONER	1902-07
JOHN HAY	1902-05	WILLIAM BENSON STOREY	1924-39
MYRON T. HERRICK	1915-29	WILLIAM H. TAFT	1906-15
ABRAM S. HEWITT	1902-03	WILLIAM S. THAYER	1929-32
HENRY L. HIGGINSON	1902-19	CHARLES D. WALCOTT	1902-27
ETHAN A. HITCHCOCK	1902-09	HENRY P. WALCOTT	1910-24
HENRY HITCHCOCK	1902-02	WILLIAM H. WELCH	1906-34
WILLIAM WIRT HOWE	1903-09	ANDREW D. WHITE	1902-03
CHARLES L. HUTCHINSON	1902-04	EDWARD D. WHITE	1902-03
SAMUEL P. LANGLEY	1904-06	HENRY WHITE	1913-27
CHARLES A. LINDBERGH	1934-39	GEORGE W. WICKERSHAM	1909-36
WILLIAM LINDSAY	1902-09	ROBERT S. WOODWARD	1905-24
HENRY CABOT LODGE	1914-24	CARROLL D. WRIGHT	1902-08
SETH LOW	1902-16		

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

# STAFF OF INVESTIGATORS FOR THE YEAR 1942

## ASTRONOMY

### MOUNT WILSON OBSERVATORY

Organized in 1904; George E. Hale, Director 1904-1923, Honorary Director 1923-1936

WALTER S. ADAMS, <i>Director</i>	ROBERT B. KING
ALFRED H. JOY, <i>Secretary</i>	PAUL W. MERRILL
ARTHUR S. KING, <i>Supt. Physical Laboratory</i>	RUDOLPH MINKOWSKI
JOHN A. ANDERSON	SETH B. NICHOLSON
WALTER BAADE	EDISON PETTIT
HAROLD D. BABCOCK	ROBERT S. RICHARDSON
WILLIAM H. CHRISTIE	ROSCOE F. SANFORD
THEODORE DUNHAM, JR.	GUSTAF STRÖMBERG
JOSEPH HICKOX	ADRIAAN VAN MAANEN
EDISON HOGE	OLIN C. WILSON
EDWIN P. HUBBLE	RALPH E. WILSON
MILTON L. HUMASON	

## TERRESTRIAL SCIENCES

### GEOPHYSICAL LABORATORY

Organized in 1906, opened in 1907; Arthur L. Day, Director 1907-1936

L. H. ADAMS, <i>Director</i>	G. W. MOREY
J. S. BURLEW	E. F. OSBORN
ALLEN CROCKER (resigned)	C. S. PIGGOT
J. L. ENGLAND	EUGENE POSNJAK
R. E. GIBSON	H. S. ROBERTS
R. W. GORANSON	J. F. SCHAIRER
J. W. GREIG	E. S. SHEPHERD
EARL INGERSON	GEORGE TUNELL
F. C. KRACEK	W. D. URRY
O. H. LOEFFLER	F. E. WRIGHT
H. E. MERWIN	E. G. ZIES

### DEPARTMENT OF TERRESTRIAL MAGNETISM

Organized in 1904; L. A. Bauer, Director 1904-1929

J. A. FLEMING, <i>Director</i>	A. G. McNISH
O. H. GISH, <i>Assistant Director</i>	R. C. MEYER
P. H. ABELSON	W. C. PARKINSON
C. J. ARONSON	R. B. ROBERTS
L. V. BERKNER	W. J. ROONEY
R. C. COILE (resigned)	W. E. SCOTT
S. E. FORBUSH	S. L. SEATON
G. K. GREEN	K. L. SHERMAN
L. R. HAFSTAD	W. F. STEINER
N. P. HEYDENBURG	O. W. TORRESON
E. A. JOHNSON	M. A. TUVE
H. F. JOHNSTON	E. H. VESTINE
M. W. JONES	G. R. WAIT
P. G. LEDIG	H. W. WELLS



## BIOLOGICAL SCIENCES

### DIVISION OF PLANT BIOLOGY

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923; reorganized in 1928 as Division of Plant Biology, including Ecology.

H. A. SPOEHR, *Chairman*  
JENS CLAUSEN  
WILLIAM M. HIESEY  
DAVID D. KECK  
WINSTON M. MANNING

EMMETT V. MARTIN  
H. W. MILLNER  
FORREST SHREVE  
JAMES H. C. SMITH  
HAROLD H. STRAIN

### DEPARTMENT OF EMBRYOLOGY

Organized in 1914; Franklin P. Mall, Director 1914-1917; George L. Streeter, Director 1918-1940

GEORGE W. CORNER, *Director*  
ROBERT K. BURNS, JR.  
LOUIS B. FLEXNER  
ALFRED GELLHORN, *Fellow*

CHESTER H. HEUSER, *Curator of the Embryological Collection*  
MARGARET R. LEWIS  
SAMUEL R. M. REYNOLDS

### DEPARTMENT OF GENETICS

Station for Experimental Evolution, opened in 1904, combined with Eugenics Record Office in 1921 to form Department of Genetics. Charles B. Davenport, Director 1904-1934; A. F. Blakeslee, Director 1935-1941.

M. DEMEREC, *Acting Director*  
AMOS G. AVERY  
A. DOROTHY BERGNER  
UGO FANO, *Fellow*  
B. P. KAUFMANN  
E. C. MACDOWELL

JAMES S. POTTER  
OSCAR RIDDLE  
SOPHIA SATINA  
MORRIS STEGGERDA  
H. E. WARMKE

### NUTRITION LABORATORY

Organized in 1907, opened in 1908; F. G. Benedict, Director 1907-1937

T. M. CARPENTER, *Acting Director*  
V. COROPATCHINSKY

ROBERT C. LEE

## HISTORICAL RESEARCH

### DIVISION OF HISTORICAL RESEARCH

Department of Historical Research organized in 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

A. V. KIDDER, *Chairman*

#### *Section of Aboriginal American History*

SYLVANUS G. MORLEY  
EARL H. MORRIS  
H. E. D. POLLOCK  
KARL RUPPERT  
ANNA O. SHEPARD  
EDWIN M. SHOOK  
A. LEDYARD SMITH  
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SOL TAX  
J. ERIC S. THOMPSON  
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ROBERT S. CHAMBERLAIN  
RALPH L. ROYS  
FRANCE V. SCHOLES  
LEO F. STOCK

#### *Section of the History of Science*

GEORGE SARTON  
ALEXANDER POGO

## RESEARCH ASSOCIATES

MARION E. BLAKE, Archaeology

PAUL S. CONGER, Biology

NEWTON B. DRURY, Study of Primitive Areas

FRANK A. PERRET, Geophysics

JOHN T. TATE, Physics

## RESEARCH ASSOCIATES ENGAGED IN POST-RETIREMENT STUDIES

A. F. BLAKESLEE, Genetics

FREDERICK H. SEARES, Astronomy

GEORGE L. STREETER, Embryology

## RESEARCH ASSOCIATES CONNECTED WITH OTHER INSTITUTIONS

ERNEST B. BARCOCK (University of California), Genetics

V. BJERKNES (University of Oslo), Meteorology

EDWARD L. BOWLES (Massachusetts Institute of Technology), Physics

JOSEPH C. BOYCE (Massachusetts Institute of Technology), Physics

E. H. BRAMHALL (University of Alaska), Terrestrial Magnetism

G. BREIT (University of Wisconsin), Physics

ROBERT B. BRODE (University of California), Physics

DIRK BROUWER (Yale University), Astronomy

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TH. DOBZHANSKY (Columbia University), Genetics

CHARLES ELTON (Oxford University), Climatology

G. GAMOW (George Washington University), Physics

FRANK T. GUCKER, JR. (Northwestern University), Chemistry

ROSS GUNN (United States Naval Research Laboratory), Terrestrial Magnetism

ARTHUR T. HERTIG (Boston Lying-in Hospital), Embryology

H. H. HESS (Princeton University), Geophysics

VICTOR F. HESS (Fordham University), Physics

A. HOLLAENDER (National Institute of Health), Genetics

EDGAR B. HOWARD (University of Pennsylvania), Archaeology and Paleontology

JAMES H. JEANS (Royal Society of London), Astronomy

EINAR JENSEN (University of Oslo), Geophysics

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REMINGTON KELLOGG (United States National Museum), Paleontology

S. A. KORFF (Bartol Research Foundation), Physics

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EDWIN D. MCKEE (United States National Park Service), Geology and Paleontology

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S. A. MITCHELL (University of Virginia), Astronomy

T. H. MORGAN (California Institute of Technology), Biology

WALTER H. NEWHOUSE (Massachusetts Institute of Technology), Geophysics

WILSON M. POWELL (University of California), Physics

ROBERT REDFIELD (University of Chicago), Anthropology

HENRY N. RUSSELL (Princeton University), Astronomy

H. C. SHERMAN (Columbia University), Nutrition

ALEXANDER SILVERMAN (University of Pittsburgh), Geophysics

JOEL STEBBINS (University of Wisconsin), Astronomy

CHESTER STOCK (California Institute of Technology), Paleontology

## OFFICES OF ADMINISTRATION

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SAMUEL CALLAWAY, *President's Secretary*

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DOROTHY R. SWIFT, *Editor*

### *Office of the Bursar*

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J. STANLEY LINGEBACH, *Assistant Bursar*

### *Investment Office (New York City)*

DEVEREUX JOSEPHS, *Investment Officer*  
PARKER MONROE, *Investment Officer*

## ORGANIZATION, PLAN, AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore, the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the Endowment Fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of the *Carnegie Institution of Washington*. (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, and the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment, and continuous effort. Many close relations exist among activities of the Institution, and a type of organization representing investigations in astronomy, in terrestrial sciences, in biological sciences, and in historical research has been effected. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publications provides means for appropriate publication.

## ARTICLES OF INCORPORATION

PUBLIC No. 260. An Act to incorporate the Carnegie Institution of Washington.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings, and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley*, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership

## ARTICLES OF INCORPORATION

to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinafter referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia,

## CARNEGIE INSTITUTION OF WASHINGTON

January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books, or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

*Approved, April 28, 1904*

# BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, December 13, 1912, December 10, 1937, December 15, 1939, December 13, 1940, and December 18, 1942

## ARTICLE I

### THE TRUSTEES

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.
2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.
3. No Trustee shall receive any compensation for his services as such.
4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

## ARTICLE II

### MEETINGS

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year unless the date and place of meeting are otherwise ordered by the Executive Committee.
2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.
3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

## ARTICLE III

### OFFICERS OF THE BOARD

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.
2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.



## CARNEGIE INSTITUTION OF WASHINGTON

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.

4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties.

### ARTICLE IV

#### EXECUTIVE ADMINISTRATION

##### *The President*

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall sign and execute on behalf of the corporation all contracts and instruments necessary in authorized administrative and research matters and affix the corporate seal thereto when necessary, and may delegate the performance of such acts and other administrative duties in his absence to the Executive Officer. He may execute all other contracts, deeds, and instruments on behalf of the corporation and affix the seal thereto when expressly authorized by the Board of Trustees or Executive Committee. He may, within the limits of his own authorization, delegate to the Executive Officer authority to act as custodian of and affix the corporate seal. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

4. There shall be an officer designated Executive Officer who shall be appointed by and hold office at the pleasure of the President, subject to the approval of the Executive Committee. His duties shall be to assist and act for the President as the latter may duly authorize and direct.

## BY-LAWS OF THE INSTITUTION

5. The President shall retire from office at the end of the calendar year in which he becomes sixty-five years of age.

### ARTICLE V

#### COMMITTEES

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication. The Executive Committee shall have power to authorize the purchase, sale, exchange, or transfer of real estate.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of five members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall have power to authorize the purchase, sale, exchange, or transfer of securities and to delegate this power. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expen-

## CARNEGIE INSTITUTION OF WASHINGTON

ditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

### ARTICLE VI

#### FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees, or as provided in Article V, paragraph 6, hereof.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

### ARTICLE VII

#### AMENDMENT OF BY-LAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

## ABSTRACT OF MINUTES OF THE FORTY-FOURTH MEETING OF THE BOARD OF TRUSTEES

The meeting was held in New York in the Board Room of the Carnegie Corporation of New York on Friday, December 18, 1942. It was called to order at 11:00 A.M. by the Chairman, Mr. Forbes.

Upon roll call, the following Trustees responded: Thomas Barbour, James F. Bell, Robert Woods Bliss, Lindsay Bradford, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Herbert Hoover, Walter A. Jessup, Frank B. Jewett, Alfred L. Loomis, Roswell Miller, Seeley G. Mudd, Henry R. Shepley, Richard P. Strong, Frederic C. Walcott, and Lewis H. Weed. The President of the Institution, Dr. Vannevar Bush, was also in attendance.

The minutes of the forty-third meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Chairmen of Divisions, Directors of Departments, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1943 were authorized:

Pension Fund .....	\$ 60,000
Administration (including Investment Office and Insurance) .	130,580
Publications (including Office of Publications and Public Relations) .....	22,380
Departmental Research Operations .....	954,270
	<hr/>
	\$1,167,230

The Chairman reported the death of Stewart Paton. As a result of balloting Henning W. Prentis, Jr., President of the Armstrong Cork Company, Lancaster, Pennsylvania, was elected to fill the existing vacancy in the Board.

Mr. Forbes was re-elected Chairman of the Board, Mr. Gifford was re-elected Vice-Chairman, and Mr. Delano was re-elected Secretary, each for the ensuing period of three years.

Walter A. Jessup, Henry R. Shepley, and Lewis H. Weed were re-elected members of the Executive Committee for a period of three years.

Walter S. Gifford, Elihu Root, Jr., and Frederic C. Walcott were re-elected members of the Finance Committee for a period of three years.

Frederic A. Delano was re-elected Chairman of the Auditing Committee for a period of three years, and Homer L. Ferguson and James W. Wadsworth were re-elected members of this Committee for the same period.

## CARNEGIE INSTITUTION OF WASHINGTON

Upon recommendation of the Executive Committee, article 2, section 1 of the By-Laws of the Institution was amended to read as follows:

"The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year unless the date and place of meeting are otherwise ordered by the Executive Committee."

The meeting adjourned at 12:50 P.M., whereupon members journeyed to luncheon, upon invitation of Mrs. Carnegie, at her home.

# REPORT OF THE EXECUTIVE COMMITTEE

FOR THE YEAR ENDING OCTOBER 31, 1942

*To the Trustees of the Carnegie Institution of Washington:*

GENTLEMEN: Article V, section 3 of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, section 3 provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1942.

During this year the Executive Committee held five meetings, printed reports of which have been mailed to each Trustee and constitute a part of this report.

A statement of activities of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. The Executive Committee is gratified at the extent to which the government has called upon the Institution for cooperation in war research, including administrative services by the President and technical services by the scientific staff. Such contributions serve a national purpose and tend also to expand the Institution's scope of usefulness in its normal sphere. The detailed estimate of expenditures for the succeeding year contained in the report of the President has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted therewith. Close attention has been given both by the Executive Committee and by the Finance Committee to the question of availability of funds for Institution activities in 1943, and budget recommendations are based upon the judgment of these Committees with respect to financial policy during the present national emergency.

The Board of Trustees, at its meeting of December 12, 1941, appointed Arthur Young and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1942. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1942, is submitted as a part of the report of the Executive Committee.

In addition to the report of the Auditor there is also submitted a financial statement for the fiscal year ending October 31, 1942, showing funds available for expenditures and amounts allotted by the Executive Committee, a customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902, and a schedule of real estate and equipment at original cost. These statements together with the tables in the Auditor's report comprise a full statement of the finances of the Institution.

A vacancy exists in the membership of the Board of Trustees by reason of the death of Stewart Paton on January 7, 1942.

Tenure of office of the following officers of the Board of Trustees will expire at the annual meeting in December: Mr. Forbes, Chairman of the Board; Mr. Gifford,

Vice-Chairman of the Board; and Mr. Delano, Secretary of the Board. Tenure of office of Messrs. Jessup, Shepley, and Weed as members of the Executive Committee, of Messrs. Gifford, Root, and Walcott as members of the Finance Committee, and of Messrs. Bliss, Delano, and Wadsworth as members of the Auditing Committee will also expire at the annual meeting.

W. CAMERON FORBES, *Chairman*  
VANNEVAR BUSH  
FREDERIC A. DELANO  
WALTER S. GIFFORD  
WALTER A. JESSUP  
HENRY R. SHEPLEY  
FREDERIC C. WALCOTT  
LEWIS H. WEED

*November 6, 1942*

**FINANCIAL STATEMENT FOR FISCAL YEAR ENDING OCTOBER 31, 1942**

	Balances unallotted Oct. 31, 1941	Trustees' appropriation Dec. 12, 1941	Reversions and transfers Nov. 1, 1941 to Oct. 31, 1942	Total available 1942	Executive Committee allotments 1942	Transfers by Executive Committee	Unallotted balance Oct. 31, 1942
<b>Departmental Research Operations:</b>							
Embryology.....		\$78,505	.....	\$78,505.00	\$78,505.00	.....	.....
Genetics.....		124,000	\$2,500.00	126,500.00	126,500.00	.....	.....
Nutrition Laboratory.....		18,700	.....	18,700.00	18,700.00	.....	.....
Geophysical Laboratory.....		159,832	.....	159,832.00	159,832.00	.....	.....
Historical Research.....		130,583	.....	130,583.00	130,583.00	.....	.....
Mount Wilson Observatory.....		209,815	.....	209,815.00	209,815.00	.....	.....
Plant Biology.....		59,970	.....	59,970.00	59,970.00	.....	.....
Terrestrial Magnetism.....		221,480	.....	221,480.00	221,480.00	.....	.....
Research Projects of Limited Tenure.....	\$2,155.07	60,000	.....	62,155.07	58,560.00	.....	\$3,595.07
Publications.....	74,869.00	52,120	2,047.26	129,036.26	63,137.96	.....	65,898.30
Administration.....	.....	117,520	600.00	118,120.00	118,120.00	.....	.....
Pension Fund.....	.....	60,000	.....	60,000.00	60,000.00	.....	.....
General Contingent Fund.....	93,008.76	10,000	73,101.42	176,110.18	9,864.62	\$3,100.00	163,145.56
Carnegie Corporation Emergency Fund	104,625.00	.....	152,191.36	256,816.36	82,360.00	.....	174,456.36
	<b>\$274,657.83</b>	<b>\$1,302,525</b>	<b>\$230,440.04</b>	<b>\$1,807,622.87</b>	<b>\$1,397,427.58</b>	<b>\$3,100.00</b>	<b>\$407,095.29</b>



AGGREGATE CASH RECEIPTS AND DISBURSEMENTS FROM ORGANIZATION, JANUARY 28, 1902, TO OCTOBER 31, 1942

RECEIPTS		DISBURSEMENTS	
<i>Securities Sold or Redeemed</i> .....	\$81,007,368.04	<i>Securities Purchased</i> .....	\$90,364,749.74
<i>Interest from Securities and Bank Balances</i> .....	49,569,010.21	<i>Accrued Interest on Securities, Purchased</i> .....	693,133.95
<i>Sales of Publications</i> .....	353,851.94	<i>Pension Fund</i> .....	1,299,394.76
<i>Colburn Estate (Bequest)</i> .....	52,015.74	<i>General Reserve Fund</i> .....	29,827.88
<i>Harriman Fund (Sale of Land)</i> .....	4,043.70	<i>Insurance Fund</i> .....	140,532.24
<i>Teetle Estate (Bequest)</i> .....	5,160.62	<i>Harriman Fund</i> .....	79.98
<i>Carnegie Corporation of New York (Endowment Increase and for Specific Purposes)</i> .....	8,335,381.24	<i>Special Emergency Reserve Fund</i> .....	63,819.41
<i>From Other Organizations and Individuals for Specific Purposes</i> .....	423,682.78	<i>National Defense Revolving Fund</i> .....	690,700.00
<i>Pension Fund (Refunds)</i> .....	91,627.93	<i>General Contingent Fund</i> .....	272,770.00
<i>General Reserve Fund (Refunds)</i> .....	177.38	<i>Carnegie Corporation of New York Emergency Fund</i> .....	45,558.64
<i>Insurance Fund (Refunds)</i> .....	13,076.02	<i>Administration Building and Addition:</i>	
<i>National Defense Revolving Fund (Refunds)</i> .....	630,977.51	<i>Construction and Site (Old Building)</i> .....	309,915.69
<i>Administration Building Addition Account, Rentals and Refunds</i> .....	18,021.09	<i>Construction (Addition to Administration Bldg.)</i> .....	416,206.07
<i>Miscellaneous Refunds and Receipts</i> .....	787,548.11	<i>Site (Addition to Administration Building)</i> .....	68,570.96
		<i>Miscellaneous Expenditures*</i> .....	40,825.37
		<i>Departmental Research Operations:</i>	
		<i>Departments of Research, Buildings and Equipment</i>	3,884,549.19
		<i>Departmental Operations</i> .....	31,277,680.51
		<i>Research Projects of Limited Tenure</i> .....	5,401,079.61
		<i>Publication</i> .....	2,828,687.15
		<i>Administration</i> .....	2,562,170.05
		<i>National Research Council</i> .....	150,000.00
		<i>Miscellaneous</i> .....	9,008.82
		<i>October 31, 1942, Cash in Banks</i> .....	\$140,549,260.02
			742,682.29
			\$141,291,942.31

\* Includes Equipment \$7,206.41. Repairs and Alterations to Old Building \$18,599.29.

# REAL ESTATE AND EQUIPMENT, ORIGINAL COST

## Administration (October 31, 1942)

### Washington, D. C.

Building, site, and equipment.....		\$848,927.91
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## Division of Plant Biology (September 30, 1942)

### Stanford University, California (Headquarters)

Buildings and grounds.....	\$74,423.46	
Laboratory.....	38,655.20	
Library.....	25,585.21	
Operating equipment.....	13,901.82	152,565.69

## Department of Embryology (September 30, 1942)

### Wolfe and Madison Streets, Baltimore, Maryland

Library.....	\$4,038.76	
Laboratory.....	18,726.82	
Administration.....	7,919.09	30,684.67

## Department of Genetics (September 30, 1942)

### Cold Spring Harbor, Long Island, New York

Buildings, grounds, field.....	\$289,989.35	
Operating equipment.....	33,591.88	
Laboratory apparatus.....	36,606.37	
Library.....	51,259.32	
Archives.....	45,488.90	456,935.82

## Geophysical Laboratory (September 30, 1942)

### 2801 Upton Street N.W., Washington, D. C.

Building, library, operating appliances.....	\$290,626.05	
Laboratory apparatus.....	171,304.96	
Shop equipment.....	21,103.00	483,034.01

## Division of Historical Research (September 30, 1942)

### Administration Building, Washington, D. C.

Operating equipment.....	\$31,953.69	
Library.....	10,809.62	42,763.31

## Nutrition Laboratory (September 30, 1942)

### 29 Vila Street, Boston, Massachusetts

Building, office, shop, and library.....	\$134,258.06	
Laboratory apparatus.....	32,669.28	166,927.34

## Mount Wilson Observatory (September 30, 1942)

### Pasadena, California

Buildings and grounds.....	\$222,458.33	
Shop equipment.....	47,255.77	
Instruments.....	684,986.05	
Furniture and operating appliances.....	147,148.26	
Hooker 100-inch reflector.....	638,507.51	1,740,355.92

## Department of Terrestrial Magnetism (September 30, 1942)

### 5241 Broad Branch Road N.W., Washington, D. C.

Building, site, and office.....	\$253,369.45	
Survey equipment.....	93,475.51	
Instruments, laboratory, and shop equipment.....	464,437.47	811,282.43

**\$4,733,477.10**

## REPORT OF AUDITORS

*To the Board of Trustees  
Carnegie Institution of Washington  
Washington, D. C.*

We have made an examination of the books and accounts of CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1942.

Income from investments and other sources has been duly accounted for and all disbursements were evidenced by paid voucher checks and/or properly approved invoices. The cash and securities were verified by certificates received from depositories and custodians. As in past years, the detail accounts of the Departments of Research in the field have been audited by the Bursar of the Institution, and we are of the opinion, as a result of reviewing the internal audit methods in force, that such internal audit is satisfactorily conducted.

The securities are stated at cost, amortized cost, or value at date acquired, this being the established custom of the Institution. In accordance with a recommendation made in February 1940 by the Institution's Finance Committee, all premiums on all obligations purchased subsequent to January 1, 1940 are being amortized on a straight-line basis to the date on which an obligation is first callable or payable at par. The amortization of the premiums applicable to the year ended October 31, 1942 amounted to \$15,694.46 and has been deducted from the cost of such obligations.

Real estate and equipment are stated at original cost and books on hand for sale at their sales prices. No provision has been made for depreciation of property owned by the Institution.

We inspected certified copies of the minutes of the meetings of the Board of Trustees and Executive Committee as authority for the appropriations and allotments made during the year.

In our opinion, on the basis of valuations stated above, the accompanying balance sheet, statement of receipts and disbursements, and detailed schedule of securities properly present the financial position of Carnegie Institution of Washington at October 31, 1942 and the transactions for the year ended that date.

ARTHUR YOUNG & COMPANY  
*Accountants and Auditors*

*New York, N. Y.  
November 25, 1942*

BALANCE SHEET OCTOBER 31, 1942

ASSETS			LIABILITIES		
<i>Investments</i>			<i>Endowment and Other Funds</i>		
Securities.....		\$31,861,866.97	<i>Capital Funds</i>		
Cash:			Endowment Fund.....	\$27,000,000.00	
Awaiting investment.....		126,052.07	Colburn Fund.....	3,315,390.72	
Reserved for current needs.....		34,280.21	Capital Reserve Fund.....		
			Harriman Fund (\$179,628.05 included in Property Fund below).....	327,428.56	
			Teplee Fund.....	5,160.62	\$30,751,290.70
<i>Property Accounts</i>			<i>Special Funds</i>		
Real Estate and Equipment at original cost:			General Reserve Fund.....		830,346.55
Office of Administration.....		\$848,927.91	Pension Fund.....		280,562.00
Departments of Research.....		3,884,549.19	Current Funds Invested.....		160,000.00
					\$32,022,199.25
<i>General Fund</i>			<i>Property Fund</i>		
Cash:			Income Invested.....		\$4,553,849.05
Income account.....	\$582,350.01		Harriman Property (Gift).....		179,628.05
Petty cash and stamps.....	500.00				4,733,477.10
		\$582,850.01	<i>General Fund</i>		
Income uncollected for the calendar year 1942.....			Current Obligations:		
Accounts Receivable.....		306,731.49	Departmental Research Operations.....	\$345,394.27	
		150,767.84	Research Projects of Limited Tenure.....	48,988.31	
			Publications.....	106,824.40	
			Administration.....	31,183.53	
			General Contingent Fund.....	172,448.18	
			Carnegie Corporation.....		
			Emergency Fund.....	189,906.36	
			National Defense Revolving Fund (includes reimbursable expenditures of \$150,767.84 carried in accounts receivable, per contra).....	300,000.00	
				\$1,194,745.05	
			Unappropriated Fund.....	5,604.29	
				\$1,200,349.34	
			Less: Current Funds Invested (see above).....	160,000.00	\$1,040,349.34
Books on hand at sale price.....		181,320.20			
Outstanding accounts on sales of publications.....		369.23	Value of Publications and Publication Paper and Supplies in Stock.....		181,689.43
Paper and supplies in stock for future publications.....		2,781.20			2,781.20
					\$37,980,496.32

# RECEIPTS AND DISBURSEMENTS FOR THE YEAR ENDED OCTOBER 31, 1942

RECEIPTS		DISBURSEMENTS	
Securities Redeemed or Sold.....	\$4,063,050.48	Securities Purchased.....	\$4,331,733.47
Interest and Dividends from Securities.....	1,289,531.04	Accrued Interest on Securities Purchased.....	6,987.40
Sales of Publications.....	3,516.32	Pension Fund.....	97,951.76
Refunds and Other Credits.....	90,174.44	General Reserve Fund.....	29,827.88
From Other Organizations and Individuals for Specific Purposes:		General Contingent Fund.....	10,861.95
Carnegie Corporation of New York.....	160,000.00	Carnegie Corporation Emergency Fund.....	12,750.00
National Research Council.....	1,200.00	Harriman Fund.....	41.53
California Institute of Technology.....	4,999.92	Departmental Research Operations*.....	1,087,251.92
Rockefeller Foundation.....	9,000.00	Research Projects of Limited Tenure.....	57,978.74
Pension Fund (Refunds).....	1,475.00	General Publication.....	25,412.06
General Reserve Fund (Refunds).....	177.38	Office of Publications.....	21,135.95
National Defense Revolving Fund (Refunds).....	630,977.51	Administration.....	116,091.56
		National Defense Revolving Fund.....	690,700.00
	\$6,254,102.09		\$6,488,724.22
		Cash in Banks, October 31, 1942:	
		Uninvested principal:	
		Awaiting investment.....	\$126,052.07
		Reserved for current needs.....	34,280.21
			\$160,332.28
		Income Account.....	582,350.01
Cash in Banks, November 1, 1941.....	977,304.42		
	\$7,231,406.51		\$7,231,406.51

\*Includes specific terminating projects administered through departments.

# SCHEDULE ON SECURITIES

Aggregate par or nominal value	Description	Ma- turity	Cost, amortized cost, or value at date acquired
UNITED STATES GOVERNMENT BONDS			
\$300,000	U. S. Guar. Federal Farm Mtg. Corp. 3s.	1949-44	\$309,210.93*
120,000	U. S. Guar. Reconstruction Finance Corp. Notes, 1s.	1944	120,000.00
460,000	U. S. of America Treasury Notes 1½s.	1946	462,084.38
575,000	U. S. of America Treasury 2s.	1950-48	579,002.95*
304,000	U. S. of America Treasury 2s.	1951-49	304,000.00
312,000	U. S. of America Treasury 2s.	1951-49	312,000.00
200,000	U. S. of America Treasury 2s.	1952-50	200,000.00
800,000	U. S. of America Treasury 2½s.	1955-52	800,000.00
1,239,000	U. S. of America Treasury 2½s.	1954-52	1,245,487.46*
300,000	U. S. of America Treasury 2½s.	1958-56	300,000.00
350,000	U. S. of America Treasury 2½s.	1967-62	350,000.00
50,000	U. S. of America Savings Defense "G" 2½s.	1953	50,000.00
50,000	U. S. of America Savings Defense "G" 2½s.	1954	50,000.00
50,000	U. S. of America Savings Defense "G" 2½s.	1954	50,000.00
\$5,110,000	Total United States Government.		\$5,131,785.72
FOREIGN BONDS			
\$55,000	Canada, Dom. of 5s.	1952	\$60,450.00
90,000	Canadian National Ry. Co. 4½s Guar.	1951	90,329.34*
100,000	Canadian National Ry. Co. 4½s Guar.	1957	112,000.00
100,000	Canadian National Ry. Co. 5s Guar.	1969	98,500.00
57,000	Canadian National Ry. Co. 5s Guar.	1969	62,344.44*
35,000	Canadian National Ry. Co. 5s Guar.	1970	38,119.77*
91,000	Canadian Pacific Ry. Co. Coll. Tr. 5s.	1954	90,835.11
100,000	Province of Alberta Deb. 4½s.	1958	93,750.00
100,000	Province of Alberta Deb. 5s.	1950	101,150.00
150,000	Province of Manitoba Deb. 4½s.	1958	142,886.77
100,000	Province of Nova Scotia Deb. 4½s.	1952	100,312.50
40,000	Province of Ontario Deb. 6s.	1943	43,137.50
250,000	Shawinigan Water and Power Co. 1st Mtg. & Coll. Tr. S. F. 4½s.	1967	238,510.42
100,000	City of Toronto Cons. Loan Deb. 5s.	1949	96,164.59
\$1,368,000	Total Foreign.		\$1,368,490.44
PUBLIC UTILITY BONDS			
\$93,000	American Gas & Electric Co. S. F. Deb. 2½s.	1950	\$94,627.50*
300,000	Arkansas Power & Light Co. 1st & Ref. Mtg. 5s.	1956	292,312.50
75,000	Blackstone Valley Gas & Electric Co. Mtg. & Coll. Tr. 4s.	1965	76,875.00
249,000	Columbus & Southern Ohio Electric Co. 1st Mtg. 3½s.	1970	267,440.95*
23,900	Commonwealth Edison Co. Conv. Deb. 3½s.	1958	23,910.75
83,000	Commonwealth Edison Co. 1st Mtg. 3½s.	1968	85,712.87
50,000	Consolidated Edison Co. of N. Y. Deb. 3½s.	1948	50,875.00
40,000	Consolidated Edison Co. of N. Y. Deb. 3½s.	1958	40,730.00
100,000	Detroit Edison Co. Gen. & Ref. Mtg. 4s.	1965	103,500.00
200,000	Gulf States Util. Co. 1st Mtg. & Ref. 3½s.	1969	213,500.00
25,000	Houston Lighting & Power Co. 1st Mtg. 3½s.	1966	25,750.00
200,000	Illinois Power & Light Corp. 1st & Ref. Mtg. 5s.	1956	196,750.00
150,000	Louisiana Power & Light Co., 1st Mtg. 5s.	1957	154,900.00
100,000	Metropolitan Edison Co. 1st Mtg. 4½s.	1968	109,470.00
100,000	Minnesota Power & Light Co. 1st & Ref. Mtg. 4½s.	1978	92,156.25
50,000	Monongahela West Penn Pub. Serv. Co. 1st Mtg. 4½s.	1960	52,000.00
98,000	Montana Power Co., 1st & Ref. Mtg. 3½s.	1966	98,980.00
100,000	New Orleans Public Service Co. 1st & Ref. Mtg. 5s.	1955	99,200.00
65,000	New York & Westchester Lighting Co., Deb. 5s.	1954	67,052.50
57,000	North American Co., Deb. 3½s.	1949	58,122.50
50,000	Northern States Power Co., 1st & Ref. Mtg. 3½s.	1967	47,500.00
100,000	Ohio Edison Co. 1st Mtg. 4s.	1967	100,266.25
100,000	Ohio Power Co. 1st Mtg. 3½s.	1968	101,500.00
100,000	Ohio Public Service Co., 1st Mtg. 4s.	1962	102,625.00
200,000	Ohlahaoma Gas & Electric Co., 1st Mtg. 3½s.	1966	205,000.00
97,000	Oklahoma Natural Gas Co., 1st Mtg. 3½s.	1955	104,507.80
100,000	Pacific Gas & Electric Co., 1st & Ref. Mtg. 3½s.	1961	102,500.00
100,000	Pacific Gas & Electric Co., 1st & Ref. Mtg. 4s.	1964	104,000.00
141,000	Public Service Co. of No. Ill., 1st Mtg. 3½s.	1968	145,230.00
60,000	Puget Sound Power & Light Co., 1st & Ref. Mtg. 4½s.	1950	56,550.00
50,000	Puget Sound Power & Light Co., 1st & Ref. Mtg. 5½s.	1949	31,900.00
300,000	Southern California Edison Co., Ltd. 1st & Ref. Mtg. 3s.	1965	313,970.20*
150,000	Southern Natural Gas Co., 1st Mtg. Pipe Line, S. F. 3½s.	1956	154,112.94*
300,000	Texas Electric Service Co., 1st Mtg. 5s.	1960	292,700.00
195,500	Texas Power & Light Co., 1st & Ref. Mtg. 5s.	1956	200,528.02
120,000	Toledo Edison Co., 1st Mtg. 3½s.	1968	121,800.00
263,000	Virginia Electric & Power Co., 1st & Ref. Mtg. 3½s.	1968	272,205.00
225,000	Wisconsin Electric Power Co., 1st Mtg. 3½s.	1968	232,875.00
\$4,810,400	Total Public Utility.		\$4,893,636.03

\*After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940. Amortization is on a straight-line basis to the date on which bonds are first callable or payable at par.

**SCHEDULE OF SECURITIES—Continued**

Aggregate par or nominal value	Description	Ma- turity	Cost, amortized cost, or value at date acquired
<b>COMMUNICATION BONDS</b>			
\$280,000	American Telephone & Telegraph Co., Conv. Deb. 3s.....	1956	\$307,703.79*
51,000	American Telephone & Telegraph Co., Deb. 3 1/4s.....	1961	51,510.00
314,000	American Telephone & Telegraph Co., Deb. 3 1/4s.....	1966	326,706.75
25,000	Mountain States Telephone & Telegraph Co., Deb. 3 1/4s.....	1968	25,500.00
52,000	New England Telephone & Telegraph Co., 1st Mtg. 5s.....	1952	51,748.00
75,000	Southern Bell Telephone & Telegraph Co., Deb. 3 1/4s.....	1962	72,375.00
<b>\$797,000</b>	<b>Total Communications.....</b>		<b>\$835,543.54</b>
<b>RAILROAD EQUIPMENT TRUSTS</b>			
\$50,000	Erie R. R. Co., 4 1/4s Guar.....	1943	\$47,960.26
88,000	Illinois Central R. R. Co., 4 1/4s.....	1943-44	84,397.19
82,000	Pennsylvania R. R. Co. 2 3/4s.....	1956	81,283.64
<b>\$220,000</b>	<b>Total Railroad Equipment Trusts.....</b>		<b>\$213,641.09</b>
<b>RAILROAD BONDS</b>			
\$200,000	Atchison, Topeka & Santa Fe Ry. Co., 1st & Ref. Mtg. 4 1/4s.....	1962	\$199,500.00
50,000	Central Pacific Ry. Co., 1st Ref. Mtg. 4s Guar.....	1949	48,250.00
100,000	Chesapeake & Ohio Ry. Co., Gen. Mtg. 4 1/4s.....	1992	99,464.29
75,000	Chicago & W. Indiana R. R. Co., Cons. 4s.....	1952	70,357.66
50,000	Great Northern Ry. Co., 1st & Ref. Mtg. 4 1/4s Std.....	1961	50,113.59
100,000	Great Northern Ry. Co., Gen. Mtg. 5s.....	1973	104,385.84
150,000	Louisville & Nashville R. R. Co., 1st & Ref. Mtg. 4 1/4s.....	2003	149,475.00
50,000	Oregon Short Line R. R. Co., Cons. 1st Mtg. 5s.....	1946	48,405.15
75,000	Pennsylvania R. R. Co., Gen. Mtg. 4 1/4s.....	1965	75,918.75
100,000	Pennsylvania R. R. Co., Cons. Mtg. 4 1/4s.....	1960	104,662.50
50,000	Pittsburgh, Cin. Chi. & St. L. R. R. Co., Gen. Mtg. 5s Guar.....	1975	51,898.98
100,000	Southern Rwy. Co., 1st Cons. Mtg. 5s.....	1994	103,580.34
70,000	Terminal R. R. Assn. of St. Louis S. F. Gen. Ref. Mtg. 4s.....	1953	63,603.92
100,000	Toledo & Ohio Central Ry. Co., Ref. & Imp. Mtg. 3 3/4s Guar.....	1960	99,000.00
200,000	Union Pacific R. R. Co., 1st Mtg. R. R. & Land Grant 4s.....	1947	218,942.61
2,084,000	Union R. R. Co., Deb. 6s Guar.....	1946	2,084,000.00
100,000	Virginian Ry. Co., 1st Lien & Ref. Mtg. 3 3/4s.....	1966	102,250.00
100,000	West Shore R. R. Co., 1st Mtg. 4s Guar.....	2361	78,140.00
50,000	Western Maryland Ry. Co., 1st & Ref. Mtg. 5 1/4s.....	1977	42,677.19
<b>\$3,804,000</b>	<b>Total Railroad.....</b>		<b>\$3,794,625.82</b>
<b>INDUSTRIAL AND MISCELLANEOUS BONDS</b>			
\$21,000	Allis-Chalmers Mfg. Co., Conv. S. F. Deb. 4s.....	1952	\$21,666.54
100,000	Atlantic Refining Co., Deb. 3s.....	1953	103,521.97*
150,000	Bethlehem Steel Corp., Conv. S. F. Deb. 3 1/4s.....	1952	148,750.00
4,000	Phelps Dodge Corp. Conv. Deb. 3 1/4s.....	1952	4,000.00
125,000	Railway Express Agency, Serial Notes 1 1/4s-2 1/4s.....	1942-48	125,000.00
98,000	Republic Steel Corp. Gen. Mtg. 4 1/4s.....	1956	101,865.37*
97,500	Republic Steel Corp. Gen. Mtg. 4 1/4s.....	1961	100,770.21*
86,000	Scovill Manufacturing Co., Deb. 3 1/4s.....	1950	87,337.78*
400,000	Shell Union Oil Corp., Deb. 2 1/4s.....	1954	384,176.25
300,000	Socony-Vacuum Oil Co. Deb. 2 1/4s.....	1955	312,990.20*
75,000	Socony-Vacuum Oil Co., Deb. 3s.....	1964	78,000.00
150,000	Standard Oil Co. of Calif. Deb. 2 1/4s.....	1966	153,593.75*
200,000	Standard Oil Co. of N. J. Deb. 2 1/4s.....	1953	203,891.89*
1,925,000	Tennessee Coal Iron & R. R. Co., Gen. Mtg. 5s (Payment Guar. by U. S. Steel Corp.).....	1951	1,925,000.00
230,000	Westinghouse Electric & Mfg. Co., Deb. 2 1/4s.....	1951	233,258.33*
148,000	West Virginia Pulp & Paper Co., 1st Mtg. 3s.....	1954	146,520.00
<b>\$4,109,500</b>	<b>Total Industrial and Miscellaneous.....</b>		<b>\$4,130,342.29</b>
<b>MORTGAGES</b>			
\$96,710.44	Lawyers Mtg. Co., Guaranteed 1st Mtg. Cdfs., Series 18397T 4 1/4%... ..	1944	\$95,602.34
100,000	Lawyers Mtg. Co., Guaranteed 1st Mtg. Cdfs. 4 1/4% No. 29940T.....	1940	98,022.20
80,000	Lawyers Title and Guar. Co., 5 1/4% Mtg. Par Cdfs. No. D 424421381... ..	1935	79,829.60
90,000	N. Y. Title and Mtg. Co., Guaranteed 1st Mtg. Cdfs., 5 1/4% No. N97... ..	1938	90,000.00
93,750	N. Y. Title and Mtg. Co., Guaranteed 1st Mtg. Cdfs., 4 1/4% No. N86... ..	1940	93,750.00
90,000	Participating Ctf. in Consol. Bond and Mtg., S. E. corner Madison Ave. and 40th St., Manhattan, 4%.....	1944	90,000.00
<b>\$550,460.44</b>	<b>Total Mortgages.....</b>		<b>\$547,204.14</b>
<b>\$20,769,360.44</b>	<b>BONDS AND MORTGAGES—Funds Invested.....</b>		<b>\$20,915,269.07</b>

\* After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940. Amortization is on a straight-line basis to the date on which bonds are first callable or payable at par.

**SCHEDULE OF SECURITIES—Continued**

Number of shares	Description	Cost, amortized cost, or value at date acquired
<b>PREFERRED STOCKS</b>		
100	American Brake Shoe and Foundry Co., 5¼% Cum. Pref.	\$12,653.50
2,010	American Cyanamid Co., 5% Cum. Pref.	22,471.25
1,500	Appalachian Electric Power Co., 4½% Cum. Pref.	159,000.00
1,500	Bethlehem Steel Corp. 7% Cum. Pref.	183,637.50
500	J. I. Case Thresh. Machine Co., 7% Cum. Pref.	62,225.00
600	Cleveland Electric Illuminating Co., \$4.50 Cum. Pref.	68,112.25
1,000	Deere & Company, 7% Cum. Pref.	28,812.50
1,125	E. I. Du Pont de Nemours & Co., \$4.50 Cum. Pref.	116,125.00
1,500	General Motors Corp. \$5.00 Cum. Pref.	187,937.50
225	Grant Co. (W. T.) 5% Cum. Pref.	7,642.76
530	Johns-Manville Corp. 7% Cum. Pref.	67,294.52
5,000	S. H. Kress Co., 6% Cum. Spl. Pref.	58,269.00
1,000	New York State Electric & Gas Corp. 5.10% Cum. Pref.	103,250.00
1,000	Northern States Power Co., \$5.00 Cum. Pref.	103,000.00
770	Ohio Oil Co., 6% Cum. Pref.	84,263.30
550	Ohio Power Co., 4½% Cum. Pref.	59,925.00
550	Oklahoma Natural Gas Co., \$5.50 Cum. Conv. Prior Pref.	62,142.51
600	Public Service Co. of Oklahoma 5% Cum. Pref.	60,900.00
1,154	Sherwin-Williams Co., 5% Cum. Pref.	127,190.29
1,000	Southwestern Gas & Electric Co., 5% Cum. Pref.	110,350.00
1,000	Standard Oil Co. of Ohio 5% Cum. Pref.	109,385.47
3,100	U. S. Steel Corp., 7% Cum. Pref.	443,407.57
26,314	Total Preferred Stocks	\$2,237,994.92
<b>COMMON STOCKS</b>		
1,800	Air Reduction Company	\$107,905.16
2,000	American Brake Shoe and Foundry Co.	87,580.95
1,500	American Can Company	136,846.00
3,300	American Cyanamid Co., "B"	95,812.55
4,000	American Radiator & Standard Sanitary Corp.	73,114.91
200	American Telephone & Telegraph Co.	21,007.50
1,600	Bethlehem Steel Corp.	125,270.00
2,600	Caterpillar Tractor Co.	175,811.00
1,900	Chase National Bank of N. Y.	61,775.00
2,400	Chrysler Corporation	226,638.50
1,500	Commercial Credit Co.	72,258.75
1,900	Commercial Investment Trust Corp.	112,346.24
150	Commercial National Bank and Trust Co. of N. Y.	26,880.00
2,700	Continental Can Co.	118,124.50
2,408	Continental Insurance Co.	87,913.30
5,500	Continental Oil Co. of Delaware	149,622.50
2,900	Deere & Company	57,720.36
980	Dow Chemical Co.	117,622.28
1,150	E. I. Du Pont de Nemours & Co.	181,861.50
1,600	Eastman Kodak Co. of N. J.	252,428.75
35	First National Bank of N. Y.	60,925.00
10,600	General Electric Co.	417,371.50
2,800	General Foods Corporation	114,615.00
7,600	General Motors Corporation	390,669.00
3,600	W. T. Grant Co.	119,318.24
440	Guaranty Trust Co. of N. Y.	115,954.00
5,300	Gulf Oil Corp.	196,858.50
900	Hartford Fire Insurance Co.	69,384.68
3,800	Humble Oil & Refining Co.	219,969.50
1,000	Ingersoll-Rand Company	107,083.00
920	Inland Steel Company	90,662.50
1,200	Insurance Company of North America	79,238.15
864	International Business Machines Corp.	117,056.84
1,000	International Harvester Co.	82,476.25
800	Johns-Manville Corp.	76,687.15
3,000	Kennecott Copper Corp.	129,293.38
4,500	Kresge Company (S. S.)	104,500.00
1,100	Liggett & Myers Tobacco Co., "B"	110,625.00
1,600	Monsanto Chemical Co.	160,453.00
4,100	Montgomery Ward & Co.	220,701.08
760	National Fire Insurance Co. of Hartford	42,942.50
5,100	National Lead Co.	108,585.50
2,000	Newberry Co. (J. J.)	94,190.00
2,600	New Jersey Zinc Co.	172,294.50
3,200	Owens-Illinois Glass Co.	197,239.00
2,900	Parke, Davis & Co.	107,042.00
2,500	Penney Co. (J. C.)	229,123.50
3,900	Phelps Dodge Corp.	145,754.79
1,200	Pittsburgh Plate Glass Co.	131,399.75
1,800	Procter & Gamble Co.	100,795.82
900	Pullman Inc.	43,073.18
1,200	St. Joseph Lead Co.	54,506.57

(Continued on following page)



**SCHEDULE OF SECURITIES—Continued**

Number of shares	Description	Cost, amortized cost, or value at date acquired
<b>COMMON STOCKS—Continued</b>		
3,100	Sears, Roebuck & Co.....	\$244,900.90
1,500	Sherwin-Williams Co.....	147,079.47
8,000	Socony-Vacuum Oil Co.....	95,645.00
4,000	Standard Oil Co., of California.....	127,044.00
2,600	Standard Oil Co. of Indiana.....	75,550.50
1,858	Standard Oil Co. of N. J.....	98,627.38
4,300	Texas Company.....	181,018.76
2,800	Timken Roller Bearing Co.....	136,062.00
3,800	Union Carbide & Carbon Corp.....	321,683.50
1,500	United Fruit Company.....	109,972.00
1,200	United States Gypsum Co.....	120,301.00
600	United States Steel Corp.....	61,573.34
2,700	Westinghouse Electric & Mfg. Co.....	289,816.50
163,265	Total Common Stocks.....	\$8,708,602.98
189,579	COMMON AND PREFERRED STOCKS—Funds Invested.....	\$10,946,597.90
	AGGREGATE INVESTMENTS (BONDS AND STOCKS).....	\$31,861,866.97

**REPORT OF THE PRESIDENT**

**OF THE**

**CARNEGIE INSTITUTION OF WASHINGTON**

**FOR THE YEAR ENDING OCTOBER 31, 1942**



# REPORT OF THE PRESIDENT

## OF THE

### CARNEGIE INSTITUTION OF WASHINGTON

In accordance with provisions of the By-Laws of the Institution, the President has the honor to report to the Board of Trustees on research activities of the year ending October 31, 1942, on financial and administrative matters, and on services which the Institution renders to the United States Government.

At the last meeting of the Board, following declaration of war, the Trustees adopted a resolution, in accordance with which the Institution is meeting all requests from the government for scientific aid as fully as its facilities and resources will permit. It was recognized that this policy would inevitably interrupt most of the normal program of the Institution. Accompanying scientific research for war purposes there is always an increase in fundamental knowledge; but war research is primarily applied research, and of relatively short range, whereas the normal program of the Institution is broad and basic. The action of the Trustees recognized that this Institution must place war research first, and suspend its peacetime activities in order to do so. The loss, even from a long-range point of view, will not be total, for the boundaries of knowledge are incidentally being extended, even though in strange ways, and some peacetime results will follow. No compromise is being made on this basis, however, and the requests of government are being met directly by the means best adapted to produce results, by every laboratory and scientist of the Institution that can be diverted to advantage.

After Pearl Harbor this country ceased

to be an oasis in a world at war, and entered upon a period of strife and sacrifice. To the Institution there is an intensified opportunity to serve the nation in its peril, and the effort indeed calls for the sacrifice of precious things. To only a minor extent can we still hope to continue progress in paths of research toward distant cultural objectives, and by keeping the road open avoid the loss of ground already gained. Not all scientific talents are of such nature as to be immediately and directly applicable to the waging of war, and hence the transition has occurred more rapidly in some departments than in others. The utmost effort of our research, however, wherever it has been possible to divert it successfully, is directed toward placing more powerful weapons in the hands of the youth of the land, and toward devising means better to protect their health in combat, by guarding against the rigors of disease and unnatural stress. To the extent of our ability and resources, and to the full effort of our personnel as it becomes determined how they can best serve, the Institution is committed to the service of the nation at war.

When this war is over it will have been amply demonstrated that the full prosecution of the war depended in no inconsiderable degree upon the presence in this country of an extensive and vigorous system of scientific research. This nation may again lapse into a dream of security; there may again be those who will indulge in wishful thinking to ward off the rigorous realities of a world of ambitious men. But it is hardly probable, after the present ex-

perience, that the American public as a whole will ever allow the national research effort to disintegrate. Whatever may be the changes of form that are possible results of the stresses of a long war, we will certainly continue extensive scientific research in some form when peace comes. There are many kinds of valuable research, and many means of organizing for its furtherance. One very essential kind thrives best when independent groups, free of artificial constraint, compete in that pleasant contest for credit and recognition where rivalry is intense but increasingly fair and friendly, and where the entire product becomes the possession of the people as a whole.

No matter what sort of world we live in after the war, the security of science should not depend wholly on its potential contribution to the direct needs of the state. There is a more fundamental reason than this for scientific research. This reason resides in the innermost groupings of

the human mind to know and to understand, and free men everywhere and at all times have given expression, in the institutions which they have created, to this urge for knowledge. The vicissitudes of an uncertain future may alter the organizational forms by which research is conducted, but so long as free men aspire, the effort to extend the boundaries of human knowledge will continue. In this the scientists of the Institution will have a part in the years after the war, for they are able scientists and are so recognized. The Institution itself may, however, need to find support in unexpected quarters, to be able to continue strongly on its way, if the exigencies of readjustment render its normal method of continuing insufficient. On the other hand, when this war is over the service which the Institution has rendered will be known, and the benefits which it can confer in times of peace should be all the more keenly appreciated after an interval of stress.

#### WAR ACTIVITIES

The policy of the Institution, in carrying on war research for government, has been to contribute the use of its facilities, the services of its regular scientific staff, and its regular overhead costs of providing administrative services and the like. The Institution is reimbursed for added out-of-pocket expenses directly attributable to the research for government. In addition, the Institution has loaned the services of some of its scientific personnel, while still continuing them on the payroll. The result has been, as would be expected, that the over-all budgets of the several departments have been substantially unchanged by reason of undertaking an extensive war research program. This is the result that was desired, for it is consistent with the wish of the Trustees that the Institution should

contribute to the war effort as far as its current resources would allow. It also makes it very clear, to one who reads our financial statement, that the Institution has certainly not profited financially by the effort; indeed, it has not asked government to carry the costs of its regular research as the effort became diverted from peace to war.

Careful attention has been given to all details of handling government funds, and a special Revolving Fund for war projects has been established to cover advances required for monthly payments of salaries and expenses representing out-of-pocket costs under contracts between the Institution and the government.

A total of 48 contracts, concerning research on 23 separate projects, have been

entered into with the Navy Department, the War Department, and the Office of Scientific Research and Development, involving a total expenditure of government funds aggregating \$1,900,000. These contracts are as nearly as possible on a cost basis and without profit to the Institution.

Every activity of the Institution has felt the effect of the war emergency, either through calls for personal service or through reorganization of programs due to work for the government. In some cases leaves of absence have permitted staff members to receive salaried appointments by the government. Services of others have been made available while they retained salaried connection with the Institution, working either in our own or in government laboratories. At the present time 34 staff members are thus on leave, and 145 others are giving full time to war research in our own laboratories or are devoting part time in various capacities to service for the government. Twenty-eight members of the scientific staff are either members, technical aides, or consultants of sections of the National Defense Research Committee. Temporary employment of about 150 additions to personnel is likewise required at present to enable the In-

stitution to meet obligations of government contracts.

In addition to his duties as Director of the Office of Scientific Research and Development, the President of the Institution has been appointed by the Joint Chiefs of Staff as Chairman of a Joint Committee on New Weapons and Equipment. This Committee is a supporting body in the organization of the Chiefs of Staff, and is concerned in an advisory capacity with the broad aspects of new weapons.

The government has formally accepted donation by the Institution of space in the Administration Building for use by the Office of Scientific Research and Development, and has expressed its appreciation of this contribution. With the exception of a few offices in the old part of the building, the government now utilizes all space available for office accommodations, and with the inauguration of work at night, the cost of operation and maintenance of the building by the Institution has steadily increased. On the other hand, certain administrative expenses which have normally occurred in former years in the form of travel and costs of meetings, lectures, and exhibits have been eliminated for the duration of the war.

#### FINANCES

As has been evident for some years, the favorable financial situation of the Institution which existed for three decades no longer continues. Excess of income over estimates for the year 1940 was sufficient to meet a small deficit in income for the year 1941 and leave a balance to apply toward the adjustment which will be necessary in balancing the budget of 1942. For the first time, however, we expect formally to draw upon reserves at the end of this year.

The lower estimated income for the year

1943 begins to render the problem acute, for the prospective yield for next year from present securities is approximately \$160,000 less than estimated income for 1942. At the same time it has become necessary, in accordance with the general trend, to increase salaries of mechanics and others whose services are essential to maintenance of research activities undertaken in the interest of the war effort. It is possible to reduce operating expenses to some degree, but it remains essential to keep our operating units intact in many instances so that

we may continue to render full-time service to the government. On the other hand, by reason of economies we have available funds in the form of balances to carry over to meet the need for support of special Institution projects and for publication without adding to the 1943 budget for such purposes.

With these considerations in mind, the budget for next year has been set up with a view to reducing to a minimum the call which will have to be made upon funds other than current income.

It is disturbing to present, for the first time in the history of the Institution, a budget which involves even a small predicted deficit. It is true that we have ample reserves for several years of deficit operation, and it is also true that current income could be increased, so that no predicted deficit would be necessary, by simply investing less conservatively, if the added risk were genuinely warranted. But, as matters stand, there is formally a small predicted deficit for 1943.

However, the broad question of where we are headed as an Institution, from a financial standpoint, is so great that it submerges the minor question of a deficit, or a series of deficits, in the war years. Our entire income is from endowment, and we are peculiarly vulnerable to trends which adversely affect endowed institutions. Unlike the universities, we have no income from student fees. Unlike the foundations, we carry extensive continuing operations, and cannot materially cut our grants to fit our income. If the readjustment after the war further reduces endowment income, we may indeed be in severe straits.

There is still some room for retrenchment. The deficit appears, for one reason, because we carry the annual grant from Carnegie Corporation of New York in a separate account, since it is of terminating

nature, and because we still hold to the objective which was prominently in mind when that grant was made, of extending the influence and aid of the Institution over broad scientific fields which we share with others. But the downward trend of income, from \$1,695,900 in 1936 to an estimated income of \$1,175,000 for 1943, if it continues, will soon cause us to retrench until only the regular operation of our departments remains, and will then embarrass our attempt to continue even these in full health.

A number of our staff have gone on leave of absence in order to accept posts in the armed services or other war agencies, under conditions where we have been temporarily relieved of salary payments. Their names have remained on our rolls, we have continued their benefits under our retirement provision, and, where conditions warranted, we have supplemented their government salaries. Moreover, we still include their salaries in making up the departmental estimates, for we expect these men back in time, and the inclusion of their salaries hence gives a true picture of our situation. For this reason there will be more than the usual unexpended funds reported by the departments at the end of this year. Part of the excess has been used, by transfer within department budgets, to defray certain unusual extra costs of service to government which it was felt should not be included in the reimbursement account, but the bulk of such salary provision will return to us. It can be placed in reserves, where it will need to be drawn upon for current operating expenses next year in view of sharply decreased income.

In accordance with action of the Board of Trustees at its last meeting, a General Reserve Fund has been established by merging the former Special Emergency

Reserve Fund with the Insurance Fund. At the same time the former so-called Reserve Fund was designated the Capital Reserve Fund, inasmuch as the principal of this fund originated as a result of stipulation of the Founder of the Institution in connection with his gift of 1911. In view of these arrangements, insurance protection for Institution property has now been increased through commercial agencies. Fire insurance, with extended coverage, has been written for a five-year period, and war damage insurance has been secured on a yearly basis on property which may be subjected to such hazards.

As an added protection in connection with war risk, duplicate copies of important or irreplaceable administrative and financial records have been deposited elsewhere than in the Administration Building.

In an effort to cooperate with the appeal of the government for voluntary purchase of war bonds, the Institution has opened a special bank account for custody of funds derived from payroll deductions authorized by staff members for such purchase of government securities.

Since its organization the Institution has enjoyed exemption from federal taxes and from real-estate taxes in the District of Columbia. During recent months consideration has been given by authorities of the District of Columbia to the question of placing the Institution on the tax roll along with a small group of other organizations which own real estate in Washington but whose programs are nation-wide in scope. There is indication that this question will be reasonably resolved, and that the Institution's present status will be maintained.

#### REVIEW

Despite interruptions to established research plans and withdrawal of many members of the scientific staff for war research, reports of Directors of Departments indicate an amount of activity in connection with the Institution's normal program which is remarkable, although it is now rapidly decreasing. The customary interpretative statements of these activities appear in the Directors' reports in the Year Book. The following brief additional comments will serve as an introduction to the full formal record.

Although many staff members of the Mount Wilson Observatory are giving full time to war service, and essentially every remaining member of the scientific staff is contributing in some way toward the solution of military problems, the program of astronomical research has not altogether ceased and a few important advances have been made. Among the results of the

many investigations undertaken at the Observatory, especial reference may be made to the increase in our knowledge of solar prominences, solar rotation, and the general magnetic field of the sun through the application of powerful interference methods; to the analysis of the gaseous clouds of interstellar space; and to the probable solution of the problem of long standing of the direction of rotation of the outer systems of stars known as the extragalactic spiral nebulae. The conclusion that the spiral arms are trailing in all such nebulae now seems to be well founded. A discovery of some dramatic interest is that of the remnants of Kepler's celebrated supernova of 1604. Faint wisps of nebulosity scattered over a field some 80 seconds in diameter and a small fan-shaped nebula showing a high radial motion seem to be all that remains of the expanding shells



thrown off in the great outburst of the original star.

Activities at the Geophysical Laboratory and the Department of Terrestrial Magnetism have been directed so exclusively to war research that there is little to report from these laboratories. On the basis of service which the cyclotron at the Department of Terrestrial Magnetism will be able to render in connection with war research, and at the instance of the Committee on Medical Research of OSRD, priorities have now been obtained for materials necessary for completion of this apparatus. It is expected that the cyclotron will be available for use during the coming winter.

Dr. Spoehr, Chairman of the Division of Plant Biology, reports a number of interesting experiments during the past year on the variability of the photosynthetic process, on certain structural elements in the higher plants, and on differences and relationships in climatic races of flowering plants. Several projects have recently been completed having to do with the influence of a desert environment on plant growth. It has been discovered that diatoms and related plants contain chlorophylls which are different from those of land plants. This is indication of fundamental differences in the photosynthetic apparatus between the two groups of plants. It will be of importance to determine whether this diversity is reflected in differences in the mechanism of the photosynthetic process and in the nature of the resulting products.

The work of the Department of Embryology has continued to develop along lines set forth by the Director, Dr. Corner, in last year's report. A significant addition to the collection of embryos is announced this year. Dr. Hertig and Dr. Rock, of Boston, working during the past six years

with financial aid from the Carnegie Corporation, have obtained a remarkable collection of human embryos of very early stages. By study of these specimens our knowledge of the development of the human embryo has been pushed back about one week, to the eighth day of gestation. Plans for obtaining still earlier stages are being worked out. This year marks also completion of a long study of the development of the rhesus monkey by Dr. Streeter, Dr. Heuser, and Dr. Hartman. Important studies on the organs accessory to the embryo, which have reached the stage of publication, are those of Dr. Flexner and Dr. Gellhorn on the physiology of the placenta, and of Dr. Speert on various physiological states and hormone relationships of the mammary gland.

Under the leadership of Dr. Demerec, there has been continuation of effective cooperation between the Department of Genetics and the Long Island Biological Association at Cold Spring Harbor. It is a pleasure also to report that Dr. Blakeslee, who retired as Director of this Department last year, has accepted a research post at Smith College, where, with cooperation of the Institution, he will have continued opportunity to go on with *Datura* researches under favorable conditions.

Detailed studies at the Department of Genetics, made by Dr. Demerec, Dr. Hollaender, and Dr. Fano, of genetic effects produced by X rays, ultraviolet rays, and neutrons show consistent differences between the actions of these radiations. As compared with gene mutations, fewer chromosomal breaks are produced by ultraviolet radiation than by X rays; whereas neutrons show a higher rate of chromosomal breaks than X rays. Working with maize, Dr. McClintock has obtained important evidence regarding the fusion of broken chromosome ends. She found that

broken ends retain their capacity for fusion for a certain period of time after breakage, but that after that period has passed they "heal" and are unable to fuse again. Nearly six years of study of the role of hormones in the regulation of the maternal instinct in rats have been concluded by Dr. Riddle and his associates, who found that pituitary-gland hormones play an important part in the production of stimuli that result in unlearned maternal behavior. Dr. Warmke has been cooperating with the Bureau of Plant Industry of the U. S. Department of Agriculture on several problems arising from the present war emergency. He is experimenting with the rubber-producing Russian dandelion and with fiber-producing hemp.

The small staff of the Nutrition Laboratory has been engaged in important war research in cooperation with groups at the Harvard Medical School. Work has continued, however, on respiratory exchange, by measurements on diabetic patients through cooperation with Dr. Joslin and Dr. Root, and certain studies on basal metabolism have been continued.

It has been possible for the most part for the Division of Historical Research to carry through the program of field studies planned by Dr. Kidder for the past season, in a series of archaeological explorations and excavations in Yucatan, Guatemala, Honduras, and Nicaragua. These projects have also been of interest in supplementing the government's program of inter-American cultural relations. Certain members of the staff of the Division have remained in Central America to complete their work. Additional data have been obtained concerning the discovery of human footprints in Nicaragua, and this was reported to the members of the Board. At the important archaeological site of Kaminaljuyu, outside Guatemala City, rich caches of pottery and jades have been found, and also many fine stone sculptures. Studies of such material which are now proceeding will add much to our understanding of the events of Maya history. Knowledge which staff members of this Division possess with regard to geographical and economic conditions in Central America is proving of aid in connection with the government's war program.

#### STEWART PATON

Stewart Paton died on January 7, 1942, in his seventy-sixth year. He was elected a Trustee of the Institution in December 1915, and at the time of his death had been in continuous service for a longer period than any other member of the Board. At the meeting of the Board on December 15, 1916, he was elected a member of the Executive Committee, on which he served until his resignation on account of ill health, in December 1938.

Dr. Paton was greatly interested in affairs of the Institution, and his counsel and advice were often sought, particularly

with regard to activities in the fields of biology and genetics. His personal contributions as a scientist and physician concerned studies in human behavior and took the form of pioneering efforts in every forward movement in psychiatry in the United States during the period of his career.

He takes his place as a member of that eminent group of former Trustees consisting of John S. Billings, S. Weir Mitchell, Theobald Smith, William S. Thayer, Henry P. Walcott, and William H. Welch.



# REPORTS OF DEPARTMENTAL ACTIVITIES AND COOPERATIVE STUDIES

## ASTRONOMY

*Mount Wilson Observatory*

*Special Projects*

## TERRESTRIAL SCIENCES

*Geophysical Laboratory*

*Department of Terrestrial Magnetism*

*Special Projects*

## BIOLOGICAL SCIENCES

*Division of Plant Biology*

*Department of Embryology*

*Department of Genetics*

*Nutrition Laboratory*

*Special Projects*

## HISTORICAL RESEARCH

*Division of Historical Research*

*Special Projects*



# MOUNT WILSON OBSERVATORY

*Pasadena, California*

WALTER S. ADAMS, *Director*

Since the entry of the United States into the war, two members of the scientific staff have been given indefinite leave of absence to devote all their time to investigations on military problems. A third member has been engaged, to the exclusion of all other work, upon various projects initiated by the Instrument Section of the National Defense Research Committee. The Office of Scientific Research and Development has entered into contracts with the Carnegie Institution for such work. Nearly all the remaining members of the staff have helped to contribute, each according to his special ability, to the solution of the many types of questions which have arisen in these investigations. A very large part of the time of the optical shop (enlarged considerably during the year), of the instrument shop, and of the engineering staff has been given to the design and construction of the instruments and equipment used in research projects relating to the war.

Two members of the operating group on Mount Wilson volunteered for service in the military forces and have been in the Army since early in 1942.

Although the scientific work of the Observatory has necessarily been maintained under considerable difficulties, the year has been an active one in all its fields of research. The gradual decrease in sunspot activity has favored investigations requiring a quiescent sun, such, for example, as spectrographic studies of solar rotation and the general magnetic field of the sun. Observations of prominences have been numerous and have been aided greatly by the use of the quartz monochromator of

the Öhman type designed for this purpose. No sunspots of the new cycle have as yet appeared, but they may normally be expected within the next year or two.

An extensive investigation of the infrared solar spectrum to a limit of  $\lambda 13500$ , made in cooperation with Mrs. Sitterly, of the Princeton Observatory, is nearing completion. The separation of solar from telluric lines and their identification according to element and energy level should make this catalogue of great value to solar physicists.

In the field of stellar research, our knowledge of the nearer stars has been considerably extended by the continuing program of the measurement of distances by the trigonometric method. The intrinsic luminosities of stars derived in this way have been supplemented to a great extent, for more distant stars, by computations based upon proper motions and radial velocities as well as upon certain spectral characteristics.

The fundamental importance of accurate determinations of stellar brightness has been recognized in several recent investigations. In one of these the scale of photographic magnitudes has been extended to  $20^m.5$ , primarily for the use of observers of faint stars in clusters and extragalactic nebulae. A very complete discussion of the colors of the stars in the Mount Wilson Polar Catalogue has led to interesting conclusions respecting space absorption in this region, mean effective wave lengths, and the probable departure of stars from black-body radiation. Photoelectric measures of B-type stars through various filters indicate that the nature of ab-

sorbing dust is much the same throughout interstellar space.

Stellar spectroscopy has always formed one of the major fields of investigation of the Observatory. In the past year especial attention has been given to physical studies of certain classes of variable stars and individual stars of exceptional interest. Among the classes of variable stars the results have shown numerous interrelationships as regards luminosity, distribution, and motion; and individual spectra have served to emphasize remarkable problems in spectral variation, bright-line emission, and combinations of widely differing spectral characteristics. As an example, the discussion of the orbit of a spectroscopic binary of the Wolf-Rayet type throws considerable doubt upon the usually accepted view of the origin of the emission bands.

The structure of the interstellar lines of ionized calcium in numerous stars has been examined with exceptionally high dispersion, and double or multiple lines have been found in a large majority of the stars. The results afford a means of determining the distribution in various parts of the sky of individual gaseous clouds distinguished from one another by differences of motion in the line of sight.

Investigations of galactic nebulae have to a large extent centered about those nebulae associated with outbursts of novae or supernovae. Direct photographs and spectroscopic studies of Nova Herculis (1934) show the emergence of an elliptical ring due to an expanding shell of finite thickness. The clearly separated diffuse and filamentary nebulosities of the Crab nebula, probably a remnant of the supernova of 1054, have quite different spectra, that of the diffuse part being continuous, that of the filaments consisting of bright lines. Theoretical considerations indicate that the supernova before its outburst was

a massive star of low hydrogen content, and that the greater part of its mass was lost in the outbreak, leaving a relatively small star of high temperature.

An interesting and somewhat dramatic discovery is that a small fan-shaped nebula and various wisps of nebulosity scattered over a field 80" in diameter in the constellation of Ophiuchus are almost certainly remnants of Kepler's supernova of 1604. The region is heavily obscured, but the spectral characteristics of the fan-shaped nebulosity and its relatively high radial velocity afford strong evidence that it forms part of an expanding nebula.

A detailed study of the pattern of obscuration in several extragalactic spiral nebulae indicates clearly which is the nearer side of these objects and hence the direction of inclination. When combined with the spectrographic data for numerous nebulae, these results define without ambiguity a direction of rotation, probably characteristic of extragalactic nebulae in general. The arms of the spirals are found to trail behind the nucleus. This gives what appears to be a definite answer to a problem of long standing in nebular research.

In addition to determinations of motions in extragalactic nebulae which have been accumulated rapidly in recent years, it has now become possible to make physical studies of the spectra of some of the brighter nebulae. Such an investigation of the nuclear emission of three spirals through measurements of line widths and contours has been completed during the past year.

Researches in the physical laboratory serve the purpose of contributing data both for the analysis of atomic and molecular spectra and for the study of astrophysical problems. Observations of the

spectra of rare earths and identification of their lines in the sun and stars afford an illustration of both purposes. Similarly, measurements in the laboratory of the statistical factors for spectral lines known

as "*f*-values" have been applied to a determination of the abundance of iron in the sun. The method has almost limitless applications to the spectra of the brighter stars.

## STAFF AND ORGANIZATION

### RESEARCH DIVISION

*Solar Physics:* Seth B. Nicholson, Harold D. Babcock, Joseph Hickox, Edison Hoge, Edison Pettit, Robert S. Richardson, Mary F. Coffeen, Elizabeth S. Mulders, Myrtle L. Richmond, Louise Ware.

*Stellar Motions and Statistics:* Adriaan van Maanen, Ralph E. Wilson, A. Louise Lowen.

*Stellar Photometry:* Walter Baade, Harold Weaver, Mary C. Joyner.

*Stellar Spectroscopy:* Walter S. Adams, William H. Christie, Theodore Dunham, Jr., Milton L. Humason, Alfred H. Joy, Paul W. Merrill, Roscoe F. Sanford, Gustaf Strömberg, Olin C. Wilson, Ralph E. Wilson, Ada M. Brayton, Sylvia Burd, Cora G. Burwell, A. Louise Lowen.

*Nebular Photography, Photometry, and Spectroscopy:* Edwin P. Hubble, Walter Baade, Milton L. Humason, Rudolph Minkowski, Sylvia Burd.

*Physical Laboratory:* Arthur S. King, John A. Anderson, Robert B. King.

*Editorial Division:* Paul W. Merrill, editor; Elizabeth Connor, librarian; Alice S. Beach, secretary and stenographer.

Alfred H. Joy has served as Secretary of the Observatory throughout the year.

### RESEARCH ASSOCIATES

Sir James Jeans, Dorking, England; Henry Norris Russell, Princeton University; Frederick H. Seares, Pasadena; Joel Stebbins, University of Wisconsin.

Dr. Russell spent the months of March and April 1942 in Pasadena, engaged chiefly in a term analysis of spectra of rare

earths, especially neutral and ionized gadolinium. As always, his discussions of astrophysical problems with members of the staff have been stimulating and suggestive. Dr. Seares with the assistance of Miss Joyner has completed an extensive discussion of the colors of stars in the Mount Wilson Polar Catalogue, deriving effective wave lengths and color temperatures and applying the results to black-body radiators of different temperatures. This investigation is now ready for publication. Dr. Stebbins during the summer of 1941 carried on measurements of the colors of numerous early-type stars and nebulae with his photoelectric photometers, being assisted in the observations by Mr. Bart Bouricius, of the University of Wisconsin.

### TEMPORARY ASSOCIATES

Dr. S. A. Mitchell, Director of the Leander McCormick Observatory, spent the months of July and August 1941 in Pasadena measuring the radial velocities of faint stars in the fields of stars of known proper motion from spectrograms which he obtained with the 60-inch telescope. Dr. John C. Duncan, Director of the Whitin Observatory, continued his direct photographic observations of selected nebulae and star fields. Dr. Erik Holmberg, of the Observatory of Lund, carried on nebular research during the summer and autumn months of 1941. He returned to Sweden in November 1941. Dr. G. P. Kuiper, of the Yerkes Observatory, spent two weeks of May 1942 in Pasadena in the measure-



ment of the proper motions of faint dwarf stars. Miss Elizabeth Scott, of the University of California, assisted in several investigations in stellar statistics during a stay of two months in the summer of 1941. Lieutenants Evinay and Erokan of the Turkish army visited the Observatory during the months of May and June 1942, for the purpose of studying its equipment and scientific program. Their journey was sponsored by the Department of State. Dr. Carl K. Seyfert, National Research Fellow, has continued his work throughout the year on the spectra of extragalactic nebulae.

Many other scientists have made brief visits to Mount Wilson and Pasadena during the past year.

#### INSTRUMENT CONSTRUCTION

*Design:* Edgar C. Nichols, Harold S. Kinney.  
*Optical Shop:* John S. Dalton, Donald O. Hendrix.

*Instrument Shop:* Albert McIntire, foreman; Elmer Prall, Myo C. Hurlbut, Fred Scherff, Oscar Swanson, Albert Labrow, Donald W. Yeager, machinists; Robert W. Kingan, assistant machinist; James Chapman, pattern maker; Harry S. Fehr, cabinet maker.

#### OPERATION AND MAINTENANCE

*Office:* Anne McConnell, bookkeeper; Sarah Shaw and Dorothea Neuens, stenographers and telephone operators.

*Operation:* Ashel N. Beebe, superintendent of construction; Sidney A. Jones, engineer; Kenneth de Huff, assistant engineer; Thomas A. Nelson, Boyd Thompson, Floyd Day, Louis S. Graf, night assistants; Anthony Wausnock and Mrs. Wausnock, stewards; Charles Dustman, Arnold T. Ratzlaff, George W. Foster, Lester Shade, janitors.

Several of the individuals whose names are listed above have been associated with the Observatory for but part of the year.

### OBSERVING CONDITIONS

The extraordinarily wet winter of 1940-1941 was followed by an abnormally dry season in 1941-1942, the total precipitation amounting to only 20.97 inches. The snow-fall was 30 inches. Observing conditions, as indicated by the accompanying table applying to the 60-inch telescope, were very close to the normal.

Owing to wartime conditions, the weekly evening lecture and public observations with the 60-inch telescope were discontinued in December. The exhibit hall on Mount Wilson with its numerous astronomical photographs and models has, however, been open every afternoon, and the regular daily lectures and demonstrations in the dome of the 100-inch telescope have been maintained.

MONTH	OBSERVATIONS		
	All night	Part of night	None
1941:			
July.....	22	7	2
August.....	25	4	2
September....	21	6	3
October.....	15	6	10
November....	19	6	5
December....	6	6	19
1942:			
January.....	11	11	9
February.....	12	7	9
March.....	13	9	9
April.....	5	14	11
May.....	24	4	3
June.....	28	2	0
Total.....	201	82	82
Mean 30 years...	204	85	75

## SOLAR RESEARCH

## SOLAR PHOTOGRAPHY

Photographs of the sun were made on 301 days of the year by Hickox, Hoge, Nicholson, and Richardson. These were distributed as follows:

Direct photographs .....	604
<i>H<math>\alpha</math></i> spectroheliograms of spot groups, 60-foot focus .....	760
<i>H<math>\alpha</math></i> spectroheliograms, 18-foot focus..	1,170
<i>H<math>\alpha</math></i> spectroheliograms, 7-foot focus..	4,000
K2 spectroheliograms, 7-foot focus..	18,000
K2 spectroheliograms, 18-foot focus..	1,130
K prominences, 18-foot focus .....	1,450

## SUNSPOT ACTIVITY

During the calendar year 1941 sunspot activity decreased notably from that of the preceding year. Observations were made on 294 days, on 2 of which no spots were visible. The monthly means of the number of groups observed daily during the past two and one-half years are shown in the accompanying table.

In 1941, 252 sunspot groups were observed, 119 less than in 1940. The northern hemisphere was the more active, showing 24 more groups than the southern hemisphere.

MONTH	DAILY NUMBER		
	1940	1941	1942
January .....	4.3	4.8	3.3
February .....	5.2	5.5	4.4
March .....	7.7	5.0	4.9
April .....	6.5	2.7	5.2
May .....	5.3	3.1	2.6
June .....	8.3	4.7	1.3
July .....	6.9	5.2	...
August .....	9.2	5.4	...
September .....	5.8	4.9	...
October .....	5.3	3.7	...
November .....	6.8	3.4	...
December .....	6.5	3.7	...
Yearly average .....	6.5	4.3	...

## SUNSPOT POLARITIES

Magnetic polarities in each spot group have been observed at least once, so far as possible. The classification of the groups observed between July 1, 1941 and June 30, 1942 is given in the accompanying table. As usual, "regular" groups in the northern hemisphere are defined as those in which the preceding spot has N (north-seeking) polarity and the following spot S polarity. In the southern hemisphere the polarities are reversed.

HEMISPHERE	POLARITY		
	Regular	Irregular	Unclassified
North .....	93	1	41
South .....	58	4	36
Whole sun .....	151	5	77

## SOLAR PROMINENCES

The monochromator designed for the *H $\alpha$*  line has been used extensively by Pettit in studies of the solar prominences. Most of the photographs have been made on 35-mm film at intervals of 1 minute with a telescope of 45 feet equivalent focal length. Especial attention has been given to eruptive prominences, coronal prominences as related to sunspots, and pairs of interactive prominences with connecting streamers. In prominences so far studied, the material moves only in one direction along the streamers and no exchange of matter seems to occur. This implies that two prominences can have masses of gas with electrical fields of opposite sign, a result of considerable theoretical interest. The length of such streamers varies from a few thousand to several hundred thousand kilometers; the breadth varies much less, being usually from 500 to 1000 km

and only rarely 4000 or 5000 km. Broad streamers deplete a prominence rapidly, two streamers 5000 km wide once having been observed to reduce a prominence 70,000 km high and 55,000 km wide to a height of 46,000 km within an hour.

Further study of 43 eruptive prominences shows that in 31 of them successive velocities were multiples by small whole numbers within the allowable errors of observation. In 12 an occasional velocity, usually the last of the series, was a multiple of the second preceding velocity instead of the first. This modification of the suggested law is required to explain only 12 of the total of 86 velocities involved in the study.

There seems to be no especially favored velocity in eruptive prominences, and the frequency of any velocity is roughly inversely proportional to the velocity raised to the power 0.8. Measurements of both top and bottom of eruptive prominences show that as the gas cloud rises, the changes in velocity of the various parts take place within a few minutes of the same instant and in some cases nearly simultaneously. The heights at which changes in velocity occur show some tendency to maxima of frequency at 62,000 and 162,000 km above the sun, but prominences have been observed to pass through both heights without changes in velocity.

A study has been made by Pettit with the 150-foot tower telescope of the widths of lines in the spectra of prominences and of the same lines in laboratory sources at known temperatures. In laboratory spectra the widths of the hydrogen and calcium lines agree with their theoretical widths if it is assumed that the measurements include intensities greater than 8 per cent of the maximum. In the spectrum of a quiescent prominence,  $H\alpha$  and  $H\beta$  show similar agreement with the theoretical width if a temperature of about  $5700^\circ \text{K}$

is assumed. No suitable quiescent prominence has been available for H and K, but measures on active prominences show widths much greater than the theoretical, the width in the streamers of one active prominence being three times that calculated. Random group velocities at right angles to the streamers not exceeding 7 km/sec would satisfy the observed line widths.

#### ULTRAVIOLET SOLAR SPECTRUM

A concave-grating spectrograph and the equipment at the Hale Solar Laboratory have been utilized by Babcock in a variety of solar investigations. Among these is a study of the spectrum of the disk, spots, and chromosphere in the region  $\lambda 3250$  to the ultraviolet limit. Numerous faint lines not recorded by Rowland have been observed, and a study has been made of the intensities of some of the strong lines near  $\lambda 3000$  for comparison with their multiplet relations. A special type of polarizer has proved useful in avoiding the effects of scattered light in the spectrograph.

Some drift-curves across the solar disk at 200-angstrom intervals between  $\lambda 4300$  and  $\lambda 3000$  have been obtained by Pettit with a 21-foot grating spectrograph and quartz monochromator. A photoelectric amplifier and galvanometer formed the recording device. The curves show a definite change in the amount of limb darkening in the 200-angstrom intervals.

#### INFRARED SOLAR SPECTRUM

The manuscript of the table of solar-spectrum lines in the region  $\lambda \lambda 6600\text{--}13500$ , in preparation by Babcock and Mrs. Sitterly with the assistance of Mrs. Coffeen, is now at Princeton, and the text is being completed. Identifications are being made through comparisons of disk and spot spectra and through structural analysis of

laboratory lines. About one-half of the 7500 lines are known to be telluric and about one-quarter of solar origin. Over 60 per cent of the known solar lines have been identified, and most of these have been assigned to multiplets. A very weak band due to atmospheric oxygen has been discovered near  $\lambda 10700$ .

A slight systematic difference, amounting to about 0.01 wave number, has appeared in the region  $\lambda\lambda 7000-7700$  between the wave-length scale of these lines and that of the Allegheny Observatory. Although too small to affect the interpretation of the results, it is now under investigation.

#### SOLAR ROTATION

Two studies of the rotation of the sun are in progress, one by Babcock, who has used the spectroscopic method, and one by Nicholson and Miss Ware, who have measured the motions of sunspots.

Babcock has combined a Lummer plate with a concave-grating spectrograph in observations of 7 lines in the green region of the spectrum. The material used is equivalent to about 100 ordinary grating spectrograms. The data give an equatorial rotational velocity close to that found by Adams with a grating spectrograph in 1908, and definitely higher than most of the values which have been announced since that time. Observations in progress include points well in on the solar radius, since the method is highly sensitive and the effects of scattered light can be eliminated by this means.

In their measurements Nicholson and Miss Ware have used material extending over four sunspot cycles. The observations have been limited to single unipolar spots in an attempt to eliminate the effect of the forward motion of the preceding spots of bipolar groups due to gradual

separation of the preceding and following members. The angular rotation is found to be  $0^{\circ}.05$  less per day than that previously derived at the Greenwich Observatory. The variation with latitude is essentially the same as that found at Greenwich.

Referred to a photosphere rotating at this slower rate, the preceding spot of a bipolar group moves forward as the group lengthens. After the following member of the group disappears, however, the preceding spot stops but does not return toward its original position as it does when referred to a faster-rotating photosphere.

#### GENERAL MAGNETIC FIELD OF THE SUN

Babcock has adapted the Lummer plate and accessories, previously used with the red lines  $\lambda 6173$  and  $\lambda 6302$ , for measurements of the general magnetic field with the lines  $\lambda 5250$  and  $\lambda 5329$ . Reductions are now in progress on 80 spectrograms which include these lines.

#### THE H AND K LINES AND MAGNETIC STORMS

Although there are good theoretical reasons for believing that terrestrial magnetic storms are caused by streams of charged particles ejected from active solar regions, so far no observational evidence has been obtained of the presence of such streams. To test the suggestion made by Chapman that a cloud of charged particles moving earthward might be detected through faint absorption lines on the violet side of the solar lines, Richardson has compared photographs of the H and K lines taken during a magnetic storm with similar photographs at a period of magnetic calm. Observations were obtained with the Snow telescope during the central period of the violent storm of September 18, 1941, and on one day preceding

as well as during the equally violent storm of March 1, 1942. These would seem to be most favorable cases so far as time is concerned.

Preliminary reductions of the microphotometer tracings give no definite evi-

dence of any faint components of the normal calcium lines before and during two of the most violent magnetic storms of the present cycle. If such lines exist, they must have an intensity less than 5 per cent of that of the continuous background.

## PLANETS AND SATELLITES

At present no reliable determination of the mass of the planet Pluto exists, solutions depending upon perturbations of the major planets having so far proved unsatisfactory. Richardson has made an attempt to determine the mass from an unexplained discrepancy in the time of perihelion passage of Halley's comet in 1910 as given by the highly accurate computations of Cowell and Crommelin.

Special perturbations were calculated from 1844 to 1908 at intervals of 512 days, on the assumption of a mass of unity for Pluto. Within the errors of the computations these corrections indicated no change

in the time of perihelion passage. Further calculations extended to 1975 make it doubtful whether Halley's comet is ever affected sensibly by the attraction of Pluto.

The investigation indicates that a planet of mass unity moving in the plane of the orbit of Halley's comet at an aphelion distance 0.1 astronomical unit greater than that of the comet would delay its perihelion passage by 6 days.

Several of the faint satellites of Jupiter have been reobserved during the year by Nicholson. The elements of the orbit of J IX have been improved and an ephemeris has been calculated for opposition.

## MISCELLANEOUS STELLAR INVESTIGATIONS

### TRIGONOMETRIC PARALLAXES AND PROPER MOTIONS

The year has seen the completion of the 500th parallax determined by van Maanen in his extensive program. Both reflectors are used, the observations being made at the Cassegrainian focus of the 60-inch and the Newtonian focus of the 100-inch telescope. Although the focal lengths are in the ratio of nearly 2 to 1, the probable error of the parallaxes with the two instruments is closely the same, about  $0''.0065$ . This comparison omits 27 stars which were observed with a rotating sector at the 100-inch telescope and were apparently subject to exceptional sources of error.

In recent years particular attention has been given in the parallax program to stars of large proper motion and presumably

faint luminosity. More than 130 stars with absolute photographic magnitudes fainter than  $+10$  have been added by van Maanen to a list of less than two dozen such stars known in 1913. Parallaxes have been determined for 17 of the 21 stars with absolute magnitudes fainter than  $+15$ .

Studies in proper motions have included measurements by R. E. Wilson of fields containing variable stars of the  $\delta$  Cephei and RR Lyrae classes, and by van Maanen of areas in the Hyades region and of the open cluster Messier 67. Two stars, out of nine for which Dr. Zwicky had found small color indices, are probable members of the Taurus cluster and should be white dwarfs. Three other faint stars have been found to share the motion of the cluster in addition to one in the region of T

Tauri of photographic magnitude about 16.5 (corresponding absolute magnitude  $+13.7$ ).

The results found for Messier 67 are based upon two photographs of the cluster taken at the Cassegrainian focus of the 60-inch telescope with an interval of 21 years. An absolute motion of  $0''.0087$  in position angle  $230^\circ$  is given by the 284 stars probably belonging to the cluster.

#### EXTENSION OF THE PHOTOGRAPHIC SCALE IN CERTAIN SELECTED AREAS

During the year final photographic magnitudes down to  $20^m.5$  have been derived by Baade for Selected Areas 51, 71, 85, and 89, again with the cooperation of H. Weaver. Selected Area 71 was included at the request of Dr. Shapley, who intends to use this area for a final check of the magnitude scales in the Magellanic Clouds. The results for seven areas will be ready for publication this fall. To check the constancy of the platinum filter, its absorption constant was redetermined in the summer of 1941: (a) with a photoelectric cell at the 60-inch by Professor Stebbins, and (b) from plates of the Polar Sequence. The new absorption constant agrees within less than  $0^m.01$  with the older value obtained in 1937.

#### EFFECTIVE WAVE LENGTHS AND COLOR TEMPERATURES

With the assistance of Miss Joyner, Seares has continued his discussion of the colors of stars provided by the Mount Wilson Polar Catalogue. An important preliminary was the determination of mean effective wave lengths as a function of temperature for the photographic and the photovisual magnitudes of the international system. It thus became possible to compute the differential corrections for atmospheric extinction depending on stel-

lar temperature and to obtain finally the relation between spectral type and color index for zero air mass. This relation is also fully corrected for space absorption. The mean color excess as a function of distance caused by the absorption in the polar region was found directly from the observational data. The differential absorption depending on temperature was computed on the assumption that the absorption varies inversely as the wave length. Incidentally, it was shown that for such calculations the direct substitution of the effective wave length into the absorption formula gives the same result for the total photographic or photovisual absorption as the complete integration over the wave-length interval.

An important application of the effective wave lengths is the calculation of theoretical color indices (international system) for black-body radiators of different temperatures. Comparison of these results with the spectrum-color relation then gave color temperatures for the different spectral types. With type A5 set at  $11000^\circ$  to fix the zero point, the result for gKo is  $4150^\circ$ . Similar calculations based on the photoelectric color indices of Stebbins and his associates give  $3750^\circ$ . The mean errors are only a fifth of the  $400^\circ$  discrepancy, which in part at least seems to be real and attributable probably to departures from black-body radiation in the stars.

#### PHOTOELECTRIC MEASURES OF STARS

Stebbins and Whitford have continued the measures of stars with a photoelectric cell and filters which isolate six spectral regions from 3500 to 10000 Å. The small deviations from the  $1/\lambda$  law of interstellar absorption, derived from reddened B stars, are found to be the same for stars in widely separated parts of the sky, showing that the nature of the dust in space is much the same everywhere.

Measures of the typical variable star  $\delta$  Cephei give light-curves in six colors which provide new material for a theoretical discussion of the cause of this class of stellar variation. The amplitude of variation at 3500 Å is four times the amplitude at 10000 Å, and there are other significant differences in the curves for different wave lengths.

#### ABSOLUTE MAGNITUDES OF STARS

From a study of the mean absolute magnitudes of long-period variables based upon radial velocities and proper motions, R. E. Wilson and Merrill have found that the luminosities of these stars are related to the period of light-variation. A period-luminosity curve is obtained in which  $\bar{M}$  reaches a maximum of  $-2.7$  for periods around 175 days, falling to  $-2.2$  at 150 days and  $+0.6$  at 450 days.

The relationship has been used to study the total motions of these stars. The mean speed is high, 74 km/sec, and the velocities exhibit the characteristics of the motions of high-velocity stars of other classes. The apices of motion lie predominantly in that half of the sky opposite to the apex of the solar motion and to the direction of galactic rotation. The preferential motion is in the same direction as that of stars in general, but for stars with the higher speeds this shifts to a direction

nearly radial with respect to the galaxy. The motions of the long-period variables are explained reasonably on the hypothesis of galactic rotation.

A similar investigation by R. E. Wilson of the mean absolute magnitudes of irregular variables of type M gives a value  $\bar{M} = -1.1$ , essentially the same as that found for the long-period variables. About 10 per cent of the stars are supergiants, for which  $\bar{M} = -3.4$ ; the remainder are ordinary giants with  $\bar{M} = -0.9$ . No correlations appear to exist with spectral type, general order of period, or character of light-variation. Excellent agreement is found with the values derived by Joy from spectroscopic criteria.

The average space motion of the irregular variables, 54 km/sec, is about midway between that of nonvariable giants of type M and that of the long-period variables; and the group motion,  $V_0 = -28.1$  km/sec, shows somewhat similar behavior. In their kinematic properties the irregular variables seem to be closely related to the long-period variables, but in their physical properties the relationship to nonvariable stars of the same spectral type seems to be more prominent.

Strömberg has now extended to giant stars of all spectral types from F to M his studies of the systematic corrections to be applied to spectroscopic absolute magnitudes.

#### STELLAR SPECTROSCOPY

The stellar spectroscopic equipment has remained without important changes or additions throughout the year. The two-prism spectrograph with collimating mirror, described in last year's report, has been used extensively at the 100-inch telescope and has proved most useful. Cameras ranging from 18 to 1.3 inches in focal length, including two of the Schmidt

type, provide for the study of spectra of stars as faint as photographic magnitude 16, as well as for observations of extragalactic nebulae.

Increases in the sensitiveness of photographic emulsions, especially some of those developed for astronomical work by Dr. Mees, of the Eastman Kodak Company, have added greatly to the efficiency of the

spectrographic instruments. Of particular value for the coude spectrograph have been the 103a-O plates, which through their remarkable sensitivity to blue and violet light have brought within the range of observation stars nearly a magnitude fainter than those observed previously.

About 1500 spectrograms have been obtained with the various instruments during the year.

### RADIAL VELOCITIES

Observations of radial velocity have been made of many stars under study primarily for statistical purposes, such as those in the Selected Areas by Strömberg and Christie, in the Taurus group by R. E. Wilson, and in the general radial-velocity program by several observers. Only 20 stars in the Selected Area program are still unobserved. Special classes of stars whose physical characteristics are being investigated have also been observed for radial velocity. These include irregular M-type variables and some eclipsing variables observed by Joy, stars of types N and R observed by Sanford, and numerous individual stars of especial interest. The differences in displacement shown by different lines have been studied by Merrill in stars of early type with emission lines. Five stars of type F with bright hydrogen lines have been discovered, in one of which, HD 59771, the measures show a rapidly expanding hydrogen atmosphere. This is most exceptional for stars with a relatively cool photosphere, and suggests an analogy with the rapid motions of prominences above the sun's reversing layer.

Determinations of the orbits of four spectroscopic binaries, including the companion of Rigel, have been completed by Sanford. For Rigel B, spectrograms of dispersion 10 Å/mm, taken with the 32-inch coude spectrograph, have been used to a large extent.

Three new spectroscopic binaries of the Wolf-Rayet type of spectrum have been discovered by O. C. Wilson. One eclipsing binary of this type, HD 193576, has been the subject of an extensive study, measures of the total absorption of the  $H\gamma$  line of the B-type component before and after eclipse being combined with photometric data from the light-curve to derive the relative dimensions of the two stars. The Wolf-Rayet star is found to be the larger. Wilson then investigated the validity of the hypothesis of an expanding envelope as the source of the emission bands in the spectrum. On the assumption of this hypothesis, one of two phenomena should be observable: (a) If the envelope is small, the part behind the eclipsing star should be occulted and the emission bands should be shifted toward the violet; (b) if the envelope is large, there should be a time lag between the observed and the predicted eclipses. Neither effect has been observed, and the evidence seems to throw considerable doubt upon the usual explanation of the origin of the emission bands.

The velocity-curve of the star HD 142983 (48 Librae), which has been rising ever since a remarkable minimum in 1937, recently reversed its upward trend, according to observations by Merrill and Sanford, a maximum apparently having occurred in 1941. The future course of the displacements shown by the various lines will be followed with interest.

Humason and Joy have continued observations of faint dwarf stars for radial velocity and spectral type. Most of them are of type M, bright hydrogen lines and bright H and K being frequent. A list of 17 M-type dwarf stars with hydrogen emission has been published.

### VARIABLE STARS

A study by Joy of the spectra of 118 M-type variables with light-curves less regular



than those of the  $\sigma$  Ceti class leads to the following conclusions: (1) The spectroscopic absolute magnitudes based upon the 1935 system show the existence of supergiants such as  $\alpha$  Orionis with magnitudes between  $-2.0$  and  $-4.5$ , but indicate that 90 per cent of the stars are normal giants like the  $\sigma$  Ceti stars with a mean absolute magnitude of  $-0.9$ . These results are in remarkably good agreement with those calculated by R. E. Wilson from proper motions and radial velocities. (2) The supergiants show a marked galactic concentration with a mean latitude of  $11^\circ$ , but the normal giants show no concentration. (3) Spectral types of supergiants, M0 to M5, are on the average earlier than those of the normal giants. (4) Corrected for solar motion, the average residual radial velocities are 18.2 km/sec for the supergiants, and 26.1 km/sec for the giants. Stars with the shorter periods show the larger velocities and the greater dispersion in velocity. (5) The mean displacement to the violet of the bright lines with respect to the absorption lines in the spectra of 17 stars showing faint emission lines at certain phases is 8.9 km/sec. This is in agreement with the results for stars of the  $\sigma$  Ceti class. (6) For a given spectral type the periods of the irregular variables are much shorter than those of the  $\sigma$  Ceti stars. They may be higher harmonics of the fundamental periods.

Joy has also continued his observations of stars of the T Tauri class, most of which are situated in obscured regions of the Milky Way, sometimes associated with nebulosity. The absorption spectra are of types F and G and indicate low luminosity. The emission spectra are unique in showing bright lines of neutral elements such as iron, magnesium, and calcium, in addition to hydrogen and many ionized elements. Helium is weak or absent, and the forbidden nebular lines are not present.

The H and K lines of ionized calcium are exceedingly strong. In many respects these emission spectra resemble that of the sun's chromosphere.

Numerous individual variable stars of exceptional spectroscopic interest have been under observation during the year. Of these BD  $+11^\circ 4673$  (AG Pegasi) is one of the most remarkable. In a fourth report upon this star Merrill finds that the 800-day cycle in the displacements of the hydrogen lines has continued but the amplitude has diminished since 1928. Progressive changes in the spectrum since 1915 include strengthening and widening of bright lines of H and He I; increasing displacements toward the violet of dark lines, indicating faster outward motions from the star; and a general increase in the ionization of the atmosphere as shown by the lines of He I, He II, Fe II, Fe III, N II, N III, Si III, and Si IV. The dark bands of TiO have gradually grown stronger until their intensities are approximately equal to those in type M1. Thus BD  $+11^\circ 4673$  enters the small group of stars with "combination" spectra. If we assume an expanding atmosphere, certain facts suggest that the velocities of atoms increase as they travel outward and that the degree of ionization also increases.

Bands in the spectrum of the N-type variable U Cygni which are especially strong near minimum of light ( $\lambda\lambda 6185, 6211$ ), previously ascribed to the  $Ca_2$  molecule, have been identified by Sanford as due to the  $CaCl$  molecule. Thus chlorine seems to be a constituent of the atmosphere of this star. These bands also appear in the spectra of other cool stars of type N.

Joy has found the irregular variable UZ Tauri, previously classified as an old nova, to be a double star with a separation of about  $3''.5$ . Both components show bright H and K and hydrogen lines and appear to be dwarf Me stars.

An interesting observation by Joy of RW Tauri at time of total eclipse indicates that the brighter B<sub>9</sub> star is surrounded by a gaseous shell or ring giving emission lines of *H*, *Mg* II, *Ca* II, and *Fe* II. These lines are displaced 350 km/sec and point to a rapid rate of rotation with a period much shorter than the period of orbital revolution. A twelfth-magnitude companion was discovered at a distance of about 1" from the eclipsing pair.

Joy has also continued his observations of variables of the RV Tauri, SS Cygni, and R Coronae types, and of high-luminosity variables in globular clusters.

#### MISCELLANEOUS OBSERVATIONS

As a result of the survey of early-type stars with the 10-inch photographic telescope and objective prism, based upon the *H $\alpha$*  line, the discovery of 119 bright-line stars of types B and A has been announced by Merrill, Miss Burwell, and W. C. Miller. For 78 of these stars the types and other spectroscopic data have been determined from slit spectrograms. This investigation also led to the discovery of the bright-line F-type stars to which reference has already been made.

A list of 33 recently discovered stars of types N and S has been published during the year by Merrill, Sanford, and Miss Burwell. Merrill has also studied stars with anomalous spectra combining *TiO* bands and bright lines which require high excitation, and a few early-type stars with spectra resembling those of c stars but believed to be of relatively low absolute magnitude.

Humason has continued his investigation of old novae with a larger dispersion (220 Å/mm) than has heretofore been used. Nine of these objects have been re-observed and confirm the early observations, which showed that in their present

state the old novae are decidedly blue, with spectra corresponding to that of the O- or early B-type stars.

Observations of faint blue stars found by Dr. Zwicky at Palomar have been continued by Humason. In addition, several stars which Zwicky found to have a bright *H $\alpha$*  on objective-prism plates have been investigated. One of these is most probably a faint galactic nova, and the others may be bright-line variable stars.

#### INTERSTELLAR LINES

The 114-inch Schmidt camera of the coudé spectrograph has been used extensively during the year by Adams in observations of interstellar lines. The high resolving power of the instrument has been particularly valuable in showing the composite structure of the H and K lines in many stars, and in making visible on plates of high sensitivity but coarse grain the other faint lines discovered in recent years. The presence of interstellar lines of neutral iron has been established by observations of the two ground-state lines at  $\lambda 3720$  and  $\lambda 3860$ , which are extremely faint.

The identification by Herzberg of the three lines at  $\lambda\lambda 3745$ , 3957, and 4232 with lines arising from the *CH* II molecule completes, with the possible exception of one or two doubtful lines, the identification of all the sharp interstellar lines so far discovered. It also provides, through intercomparison of the intensities of  $\lambda 4300$  *CH* I and  $\lambda 4232$  *CH* II, a means of determining the numbers of *CH* molecules in each state along the line of sight in interstellar space. The observations already made show marked differences in the relative intensities of these lines. For example, in the spectra of the two stars  $\zeta$  Persei and  $\xi$  Persei, which lie but a few degrees apart in the sky and have H and K lines of the

same order of intensity, the ratios of  $\lambda 4300$  to  $\lambda 4232$  are about 5:1 and 1:5, respectively.

Under the high resolution of the coudé spectrograms, complex structure of the H and K lines is found to be the rule rather than the exception. Of the 43 stars investigated, 10 show single interstellar lines and the remaining 33 double or multiple lines. Complex lines are especially numerous in the stars observed in Orion, Ophiuchus, Sagittarius, and Cygnus, and single lines in Perseus and Scorpius. Since the components of the complex lines are doubtless due to individual gaseous clouds and are separated by the relative motions of these clouds in the line of sight, meas-

urements of radial velocity afford a means of identifying the different clouds and determining their extent.

Some individual stars of especial interest are:  $\nu$  Sagittarii, in which H and K are well marked double lines with the components separated by 0.22 Å;  $\mu$  Sagittarii, with triple and possibly quadruple components of very unequal intensities; and P Cygni, with two definite components not fully resolved. Three lines due to CH II and one due to CH I are present in the spectrum of P Cygni; and the line  $\lambda 4232$  of CH II is visible in  $\nu$  Sagittarii, the only star of comparatively advanced type of spectrum in which this line has been observed.

## GALACTIC NEBULAE

The principal results in the field of galactic nebulae include the definitive interpretation of the spectrum of the Crab nebula (supernova of 1054) by Minkowski, further information concerning the remnant of Kepler's supernova of 1604 by Baade and Minkowski, and the detection of the emerging structure in the expanding shell around Nova Herculis (1934) by Baade. In addition, spectrographic data have been obtained on the filamentary nebula in Cygnus and the inner nebulosity around R Aquarii by Humason, and the distribution of light along a diameter of the typical planetary NGC 6572 has been investigated spectrophotometrically by Seyfert.

### EXPANDING SHELL AROUND NOVA HERCULIS (1934)

Direct photographs obtained by Baade in the spring of 1942 indicate that the surface brightness has declined much faster during the past two years than can be accounted for on the assumption of constant total brightness and increasing size of disk.

A star is now easily seen at the center, and the true structure of the shell, apparently that of an elliptical ring nebula, is beginning to emerge. This interpretation of the structure is confirmed by a large-scale spectrum of the nebulosity obtained on June 8, 1942, by Humason and Baade. The N I and N II lines appear as elliptical rings such as would be expected from an expanding shell of finite thickness.

### SPECTROGRAPHIC STUDY OF THE CRAB NEBULA REMNANT OF THE SUPER-NOVA OF 1054

The spectrographic study of the Crab nebula has been concluded by Minkowski after an extension of the observations into the red and the ultraviolet. The line emission spectrum of the filaments contains lines of H, He I, He II, [N II], [O I], [O II], [O III], and [S II]. The H lines are relatively faint, probably owing to low abundance of hydrogen. The high intensity of the filaments in the red is due to the [N II] and the unusually intense [S II] lines. The spectrum of the diffuse

nebosity forming the main mass is continuous except for a faint discontinuity at the Balmer limit. Practically the entire energy emitted by the nebula is contained in the continuous spectrum, whose intensity distribution deviates from that of a black body, the color temperature being about  $8400^\circ$  at  $\lambda 4500$ , and  $6700^\circ$  at  $\lambda 6000$ .

In the absence of absorption in the nebula, the continuous spectrum cannot be due to scattering and must be a true emission spectrum. The only physically justified assumption is that the continuous spectrum is produced by free-free and free-bound transitions of electrons in the very highly ionized gas. On this assumption, the observed intensity distribution in the continuous spectrum finds a satisfactory explanation. The electron density of the diffuse mass is of the order  $10^8 \text{ cm}^{-3}$ , the electron temperature of the order  $50,000^\circ$ , the mass about 15 solar masses, and the hydrogen abundance probably low. The central star has a temperature of the order of  $500,000^\circ$ , a radius of 0.020 solar radius, and a total luminosity of 30,000 solar units. These results as a whole indicate that before their outbreak, supernovae of type I are massive stars of low hydrogen abundance. During the outbreak, the star ejects the greater part of its mass and begins to develop into a white dwarf. The present high temperature and high luminosity of the central star of the Crab nebula indicate that this stellar remnant of the supernova of 1054 has not yet finished the transformation into the degenerate state.

#### NEBULOSITY AROUND NOVA OPHIUCHI (1604)

Long-exposure photographs in the red, obtained by Baade, show that the fan-shaped mass he discovered last year is only a part of the nebosity surrounding

the former supernova, and that faint wisps are scattered over a field about  $80''$  in diameter. Evidently the obscuration in front of the nebula is not only very heavy, as was pointed out in last year's report, but also quite variable over the field.

The spectrum of the nebosity has been observed in the red by Minkowski. The combination of a plane grating (400 lines per mm) with a solid Schmidt camera,  $f/0.65$ , giving a dispersion of 400 Å/mm, has shown itself very useful for this purpose. The spectrum of the nebosity consists of the lines  $[O \text{ III}] \lambda 5007$ ,  $[O \text{ I}] \lambda 6300$ ,  $[N \text{ II}] \lambda \lambda 6548, 6584$ ,  $H\alpha$ , and  $[S \text{ II}] \lambda 6731$ . The spectrum is very similar to that of the filaments of the Crab nebula, especially as regards the low intensity of  $H\alpha$  relative to the  $[N \text{ II}]$  lines. The intensity of  $[O \text{ III}] \lambda 5007$ , however, is much less than in the Crab nebula. This is evidently due to heavy space reddening, and a color excess of about 2 magnitudes is suggested. The radial velocity is  $-200 \text{ km/sec}$  at the (north following) tip of the fan-shaped nebosity and probably about  $-260 \text{ km/sec}$  at the (south preceding) base. The velocity is too high to admit any interpretation other than that the fan-shaped nebosity is part of an expanding nebula, the center of expansion being situated closer to the base than to the tip.

#### DISTRIBUTION OF LIGHT IN NGC 6572

From a spectrophotometric study of the distribution of light along a diameter of the planetary NGC 6572, Seyfert has found that the luminosity gradients in the emission lines  $N_1$ ,  $N_2$ ,  $\lambda 4471$ ,  $\lambda 4363$ ,  $\lambda 3869$ , and the hydrogen lines are remarkably similar. The  $O \text{ II}$  doublet,  $\lambda 3727$ , however, gives an image 20 to 30 per cent larger than the mean of the other monochromatic images that have been investigated. The results are consistent with Berman's

earlier investigations of monochromatic images of the nebula.

#### MISCELLANEOUS

Humason and Baade have succeeded in obtaining a number of long-exposure spec-

trograms of faint wisps of nebulosity within the great Cygnus Loop for the purpose of investigating expansion in the line of sight. Humason has also obtained additional spectra of the inner emission nebulosity around the variable star R Aquarii.

### EXTRAGALACTIC NEBULAE

The principal results in the study of extragalactic nebulae are the completion of investigations of the direction of rotation in spirals by Hubble, and of nuclear emission in spirals by Seyfert. In addition Baade has identified an eclipsing binary and a normal Cepheid with the unusual period of 146 days in IC 1613, and Hubble and Humason have made considerable progress in the observing program which will eventually lead to a general catalogue of the fundamental data furnished by nebular spectra.

#### DIRECTION OF ROTATION OF SPIRALS

Hubble has found that in 15 spirals for which the necessary data are available, the dissymmetry of obscuration combined with the character of the spiral pattern is definitely correlated with the sense of the spectrographic rotation. On the assumption that the tilt is indicated by the dissymmetry of obscuration, all 15 nebulae are rotating in the same direction with respect to the spiral patterns.

In 4 spirals, NGC 3190, 4216, 4258, and 4527, the actual direction is determined by dark lanes which, because they are silhouetted against the nuclear bulges, unambiguously identify the nearer sides of the nebulae. In these nebulae, the arms are trailing behind the nuclear regions. The results are the basis for the working hypothesis that the arms are trailing in all spirals, and that the greater obscuration identifies the nearer side of the projected image of a nebula.

#### NUCLEAR EMISSION IN SPIRALS

Seyfert has continued his investigations of nuclear emission in spirals with especial emphasis on NGC 1068, 3516, and 4151. The emission lines and their relative intensities in these nebulae (as well as NGC 1275 and 4051) show a general similarity to the lines in the planetary NGC 7027. The lines are superposed on G-type continuous spectra in which the intensity distributions correspond to temperatures of  $5250^\circ$  for NGC 1068 and 3516, and  $4750^\circ$  for NGC 4151. The ratios of light in the emission lines to the total luminosities (emissions plus continua) in the photographic region are about 13, 5, and 20 per cent for NGC 1068, 3516, and 4151, respectively.

The line contours in NGC 1068 fall into two main groups, with line widths ranging from 2400 km/sec for  $\lambda 3869$  and  $\lambda 3968$  of [Ne III] to 3600 km/sec for  $\lambda 6717$  and  $\lambda 6731$  of [S II]. The four lines N<sub>1</sub>, N<sub>2</sub>, H $\beta$ , and  $\lambda 3869$  have absorption cores, and considerable evidence, including wave lengths and equivalent widths, suggests that the apparent central reversals may be due to superposed absorption lines arising from the G-type continuum.

In NGC 3516, the hydrogen lines are extremely broad, shallow bands ( $> 100 \text{ \AA}$ ), whereas N<sub>1</sub> and N<sub>2</sub> are relatively narrow. In NGC 4151, the contours of the forbidden lines and of the cores of the hydrogen lines are closely similar. They are about 1000 km/sec wide and show pro-

nounced asymmetry. The bright cores of the hydrogen lines  $H\alpha$  to  $H\delta$  are superposed on fainter wings, each about 7500 km/sec wide. The spiral NGC 7469 (for which Dr. Mayall first reported an emission spectrum) has hydrogen lines with wide wings resembling those observed in NGC 4151.

#### SPECTRA OF NEBULAE

Spectra of 82 nebulae, 60 of which had been previously unobserved, were obtained during the year by Hubble and Humason. The Mount Wilson collection now includes spectra of 370 nebulae out of the total of 440 observed at all stations. Most of the spectra are on a small scale, but those of 50 nebulae are on an intermediate scale, and those of 4 nebulae on a sufficiently large scale (65 A/mm and larger) to permit the study of line contours.

#### LABORATORY INVESTIGATIONS

##### RARE-EARTH SPECTRA

Further studies of rare-earth spectra by A. S. King have dealt with gadolinium and dysprosium, and a beginning has been made upon terbium. The completion of the temperature classification of  $Gd$  lines involved additional work on the ultraviolet spectrum and improvement of the data for other regions. The final list, from  $\lambda_{2135}$  to  $\lambda_{10670}$ , contains 5732 lines, extending the spectra of  $Gd$  I and  $Gd$  II to lines of low intensity. At wave lengths shorter than  $\lambda_{2700}$ , where very few lines had previously been measured, the lines of  $Gd$  III are prominent. The strongest of these, some from such low atomic levels as to appear in the arc spectrum, are listed. A comparison with the solar spectrum shows that many low-level lines of  $Gd$  II, present in the furnace spectrum, coincide with unidentified solar lines. If the probability

##### VARIABLES IN IC 1613

Baade has obtained a spectrum of a Cepheid in IC 1613 with the exceptionally long period of 146.35 days. The star was near maximum ( $m_{pg} = 17.5$ ). The spectral type was K2 (based on the intensities of  $Ca$   $\lambda_{4227}$  and the  $Sr$  pair,  $\lambda_{4215}$  and  $4077$ ). The supergiant character of the star is indicated by the great strength of the hydrogen lines. The data remove the last doubts that Cepheids with periods up to 150 days (and perhaps 200 days) do occur. Periods longer than 50 days, however, are extremely rare.

Another interesting variable in IC 1613 has proved to be an eclipsing binary with a period of 3.775 days. Both the color and the density (derived from the photometric orbit) indicate that the main component is an early B-type star. The absolute magnitude of the system is  $-2.6$ .

that these lines occur in the sun is confirmed by the term analysis being made by Albertson and Russell, a considerable increase in the number of  $Gd$  solar lines over those identified in the *Revised Rowland* table of solar wave lengths will result. No evidence of  $Gd$  I in the sun has thus far been found.

Dr. Russell has extended the analysis of the gadolinium arc spectrum and has derived an ionization potential of 6.16 volts. Further analysis is in progress.

The spectrum of  $Dy$  has been examined from  $\lambda_{3150}$  to  $\lambda_{6800}$ , chief attention being given to the lines of  $Dy$  II and their classification by means of the furnace spectrum. As in the case of  $Gd$ , agreement with solar lines is found for many of the strong low-level lines of  $Dy$  II, as well as for the few identified in the *Revised Rowland*. The  $Dy$  spectrum has a group of very strong

low-temperature lines in the violet which reverse easily in the furnace—a type unusual in rare-earth spectra. The strongest of these lines, when not masked, are identified in the *Revised Rowland* with faint solar lines, and, before the furnace spectra were available, were ascribed to *Dy* II. They are now shown to be due to *Dy* I, this being the second rare earth whose neutral lines have been observed in the sun. Those of a third element, europium, are found only in the sunspot spectrum.

#### CALCIUM OXIDE

A group of green and orange bands, present in many red stars, and tentatively ascribed to calcium oxide, has been examined in the electric furnace by A. S. King. The oxide origin was confirmed when the bands appeared with high intensity in the furnace spectrum of calcium with oxygen passing over the metal, but were absent when calcium was vaporized in vacuum at the same temperature.

#### ABUNDANCE OF IRON IN THE SUN

A value for the abundance of neutral iron atoms in the sun has been derived by R. B. King. Solar equivalent widths from Allen's tables and the Utrecht Atlas in conjunction with absolute *f*-values obtained recently in the laboratory were utilized. Twenty-three strong iron lines, on the square root, or damping, portion of the solar curve of growth, for which absolute *f*-values are available were used. A damping constant of 10 times the classic value and an excitation temperature of  $4400^\circ$  were assumed in making the computations. The total number of neutral iron atoms per square centimeter was found to be  $4.3 \times 10^{18}$ .

The cause for small but apparently real systematic differences between the results for abundance given by lines of different

multiplets is as yet obscure, since several factors may be involved. Laboratory investigations by Minkowski and R. B. King have shown that the differences cannot be due to pressure broadening alone, since no similar differences are found for these lines broadened by atmospheric pressure at  $2890^\circ$  in the furnace. The suggestion is made that under solar conditions broadening due to "natural" widths of the lines is not negligible. An extension of the laboratory *f*-values for *Fe* to lines of higher level which has been in progress may aid in settling this question.

#### RELATIVE *f*-VALUES

The work on relative *f*-values for *V* I, *Ni* I, and the higher-level lines of *Fe* I has been continued. In vanadium almost all lines of temperature classes I–IV are observed in absorption at a furnace temperature of  $3000^\circ$  C. For the present, however, it has been decided to limit the observations to lines of classes I–III in the astrophysical region of the spectrum. Measurements on a large part of these lines are complete.

#### RULING MACHINES

Some minute errors of the accidental type in the smaller ruling machine have been traced by Babcock and Prall to the thrust bearing of the screw. To bring these under control the plan has been devised of subjecting the bearing to a definite, constant load, large as compared with the operating stresses, and applied directly to the screw itself. The mechanical parts needed to test this method are nearly completed.

The larger machine, with its capacity for ruling gratings of very great size, for example metallic gratings from which replicas can be made for use as objective

gratings, has been modified to admit of spacings between 600 and 1000 to the inch and lines up to 18 inches long. Because of the coarse spacing, remarkable concentration of the diffracted light is possible. Numerous small rulings of excellent quality have been made, and the problem of

producing a large ruling surface with suitable properties is being investigated. Evaporated and electroplated metallic films, alloys of soft metals, wax, and plastics have been tested, with the result thus far that a lead-tin alloy seems to be best adapted for the purpose.

## CONSTRUCTION AND MAINTENANCE

### DESIGN AND INSTRUMENT SHOP

About 70 per cent of the time of the department of engineering and design during the past year and 55 per cent of the time of the instrument shop have been devoted to the design and construction of apparatus and instruments, usually experimental, for military purposes. The instrument and optical shops have cooperated closely in this work.

The mounting of the new 10-inch photovisual telescope has been completed, and this instrument should soon be in operation. Other equipment which has been designed and partially constructed includes a small prime-focus spectrograph, a projection measuring machine, and the automatic microphotometer planned by Whitford and O. C. Wilson.

E. C. Nichols, assisted by H. S. Kinney, has continued in charge of the department of design, and Albert McIntire of the instrument shop.

### OPTICAL SHOP

A very large part of the work of the optical shop, which has been expanded to include a part of an adjoining building, has consisted in the development of methods of manufacture and testing of optics

for military use. D. O. Hendrix has devoted his entire time to this work, and John Dalton has been completing the figuring of the three-component objective of the 10-inch photovisual telescope.

### BUILDINGS AND GROUNDS

Both on Mount Wilson and in Pasadena, construction has been limited to repairs and general maintenance except for such changes as have been necessitated by the war projects in progress. Several buildings have been repainted and the paving of the road extending through the Observatory property on Mount Wilson has been completed. A wire fence, enclosing the laboratory, powerhouse, and living quarters on the southern side of the mountain top but allowing the public access to the main telescope buildings, has added greatly to the comfort of the observers and others living on the mountain. This work has been in charge of A. N. Beebe, superintendent of construction.

A large part of the telephone line, including many poles, has been replaced during the year by Sidney Jones, engineer, and Kenneth de Huff, assistant engineer. Connections with this line have been afforded to the U. S. Signal Corps and other military observers on Mount Wilson.

## THE LIBRARY

The library now contains 14,857 volumes, together with large collections of pamphlets and lantern slides. During the year

298 volumes were added, 56 by purchase, 43 by gift, and 199 by binding. From the 200 observatories and research institutions



whose publications generally come to the Observatory, very little material has been received because of the war. The number

of periodicals received during the year has dropped from 140 to 87; 29 of these are gifts or exchanges.

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## SPECIAL PROJECTS: ASTRONOMY

DIRK BROUWER, Yale University Observatory, New Haven, Connecticut. *Program for the determination of systematic corrections to fundamental catalogues from observations of minor planets.* (For previous report see Year Book No. 40.)

The number of plates obtained for this program during the year was 569, of which 181 were secured at the Yale Southern Station in Johannesburg, 227 at New Haven, and 161 at the Allegheny Observatory of the University of Pittsburgh. This number does not include the observations obtained at the Leiden Observatory. The work of that observatory was interrupted for a few months in the summer of 1940, but resumed in August of that year. Reductions of the Leiden observations for the year 1940 were received in manuscript. No report for the year 1941 has been received beyond word that the work was being continued.

The measurement of plates at Yale Observatory has been continued at an increased rate, the number of plates measured during the year being 751. This increase was made possible primarily by the addition to our staff of Dr. Gustav Land. Both Dr. Land and Miss Ruth J. Huff devoted full time to this part of the work.

Reductions of the measurements have been made under the supervision of Miss Louise F. Jenkins, but no attempt has been made to keep in step with the measurements. Greater concentration on the reductions will soon become desirable.

The calculation of the perturbations of 15 asteroids for 24 years, 1924 to 1948, was completed, and the numerical integration of 5 orbits was extended backward to the year 1924. Of the entire first-integration program of 15 planets, less than 40

per cent remains to be done. A large part of the uncompleted work concerns the planets Ceres, Pallas, Juno, and Vesta. For these planets the Astronomisches Rechen-Institut in Berlin furnished annually extensive ephemerides of a quality that was more than sufficient for the observational requirements. On this account work on these 4 orbits could be delayed until the orbits of the other planets on the program had been fully determined. During the past year first integrations and orbit corrections for Ceres and Pallas were made at Yale Observatory by Dr. Hans G. Hertz and Dr. Brouwer. Dr. Paul Herget, of the Cincinnati Observatory, gave his valued cooperation in this part of the program, contributing numerical integrations and orbit corrections for the planets Juno and Vesta. The orbits of these 4 planets are now ready for accurate integrations over the 24-year period by the Thomas J. Watson Astronomical Computing Bureau.

Owing to the progress made with the numerical integration of the orbits, the time has now arrived when useful comparisons of the orbits with observations in numerous oppositions can be made, preliminary to further improvement of the orbits. For the planet (7) Iris such work was undertaken by Mr. Oscar T. Schultz, of the U. S. Naval Observatory. He succeeded in representing the observations in eight oppositions with a highly satisfactory degree of accuracy. A similar discussion of the orbit of (57) Mnemosyne by Dr. Land is now in progress.

S. A. MITCHELL, University of Virginia, Charlottesville, Virginia. *Astronomical studies at the Leander McCormick Observatory*. (For previous reports see Year Books Nos. 38 to 40.)

For a hundred years, astronomers have been on a constant search for faint or invisible companions of bright stars. In 1844, in order to explain the variable proper motions of Sirius and Procyon, Bessel predicted the presence of a companion to each of these bright stars. In 1861, Alvan G. Clark discovered the companion of Sirius, in itself one of the most interesting stars in the sky, though the companion is 10,000 times fainter than the primary. In 1896, Schaeberle discovered the companion of Procyon. In a similar manner, through the variable proper motion of an 11th-magnitude star on the McCormick parallax program, Dr. D. Reuyl found that the star Ross 614 is a double, the first star of the Sirius type to be discovered by photographic processes. Ross 614 has been followed for several years, and the period is about 15 years. The companion has not been seen visually. Dr. Reuyl has found a second star with variable proper motion, Cincinnati 1244. The masses of the invisible companions must be less than one-tenth the mass of the sun. These stars are both of dwarf M type with emission lines. It appears that stars of this type have a high probability of being double.

Duplicity has been found directly from McCormick photographs for the two stars Wolf 424 and BD +19°5116. The photographs reveal that the former is in fairly rapid motion, the distance having decreased from 0".8 to 0".3 in about one year. In view of the fact that the scale of the McCormick photographs is 1 mm = 20" of arc, the centers of the components of Wolf 424 are now separated by only 0.015 millimeter. This is far too small a separation to permit measurement directly,

but none the less the exquisite definition of the McCormick refractor permits the detection and measurement of the elliptical character of the images of Wolf 424 as compared with the circular images of nearby stars of the same magnitude. For all cases in which duplicity has been established, an attempt is being made to determine the masses.

Wolf 630, the visual binary of shortest known period, 1.8 years, and of angular separation 0".2, is being followed photographically by Dr. Reuyl. The feature of particular interest in this work is the fact that preliminary results of the measures seem to indicate inequality of the masses in spite of the fact that the photovisual magnitudes of the components are equal.

Another McCormick research on an interesting double star has been conducted by Dr. Reuyl with the collaboration of Dr. Erik Holmberg, of the Lund Observatory, Sweden. By the use of coarse wire grating placed before the object glass, Hertzsprung many years ago showed that for double stars of unequal but bright components of fair angular separation, by the use of a grating with appropriate widths of wires and interspaces, the first-order spectra of the principal star could be made equal in magnitude to that of the fainter companion. Hertzsprung with the Potsdam and Johannesburg refractors, and Reuyl with the McCormick refractor have obtained photographs extending over many years for the double star 70 Ophiuchi. The measures of the McCormick grating photographs together with those on the regular parallax series combined with the measures of the Potsdam and Johannesburg photographs were compared with Strand's orbit. These comparisons seemed

to give fairly positive information that 70 Ophiuchi is accompanied by a third invisible star. The assumption of a circular orbit about the A or B component of 70 Ophiuchi, together with the period of 18 years, seems to indicate the smallest mass yet known for any stellar object, namely 0.01 to 0.02 of the mass of the sun.

Trigonometric parallaxes continue to be the chief research at the McCormick Observatory. Through the kindness of Dr. Kuiper, of Yerkes and McDonald observatories, a number of stars with large spectroscopic parallaxes have been put on the McCormick program. For many of these stars of M type, trigonometric parallaxes have been derived at McCormick.

The second proper-motion program of the McCormick Observatory is nearing completion. The measures of both the motions and the magnitudes of the 11,300 stars involved have been finished and the spectra for about 7500 of the stars have been determined. The proper motions in the first publication were reduced to the system of the General Catalogue. The motions of all stars in both the first and second investigations have now been reduced to the FK3 system. The motions of the more than 29,000 faint stars in the two investigations will be discussed independently and in combined solutions.

The Observatory was represented at the Symposium on Galactic Structure held May 2-3, 1941, under the auspices of the New York Academy of Science by Dr. Emma T. R. Williams, who contributed a discussion of mean parallaxes derived from peculiar motion.

Dr. A. N. Vyssotsky represented the Observatory at the Inter-American Astrophysical Conference held February 17-25, 1942, to celebrate the inauguration of the National Astrophysical Observatory at Tonanzintla, Mexico. He reported on the spectroscopic work in progress with the

10-inch Cooke prismatic camera, and pointed out, among other things, the possibilities for the discovery of stars with peculiar spectra. Thus, to date he has picked up accidentally 9 new S-type stars and 4 new planetary nebulae. The total number of new dwarf M stars found spectroscopically on McCormick plates has now reached more than 50.

Measurement of proper motions of the Cepheids is progressing in satisfactory manner. As indicated in earlier Year Books, this research is being conducted in cooperation with the Mount Wilson Observatory. The measures for the 90 regions already finished by Dr. Mitchell show an average internal probable error of  $0''.0022$  for the proper motion of the Cepheid referred to about 16 surrounding stars.

During the past year astronomers from other institutions have been in residence at McCormick in order to make use of the spectra of faint stars obtained with the 10-inch Cooke refractor. Father W. J. Miller, a graduate student of Harvard Observatory, spent six weeks in classifying the spectra of more than 2000 stars and in comparing his system of classification with that of the southern part of the Henry Draper Catalogue. Similarly, Dr. A. Marguerite Risley, of Randolph-Macon Woman's College, classified the spectra of 4000 stars. In each case, the spectra are to be used in connection with the statistical investigations of the structure of the Milky Way in cooperation with Harvard College Observatory.

Another contribution by means of the 10-inch Cooke telescope is the set of 332 photovisual sequences distributed uniformly over the sky from  $-15^\circ$  to  $+75^\circ$  declination. These were derived from equal-altitude polar comparisons by Mr. C. A. Wirtanen, and show very satisfactory agreement with the I Pv system.

In the summer of 1941, while in residence at the Mount Wilson Observatory, Dr. Mitchell by means of the 60-inch reflector obtained the spectra of about 100 A and K stars of the 10th magnitude for the determination of their radial velocities. The stars for this program were selected

from the second McCormick proper-motion investigation.

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## GEOPHYSICAL LABORATORY

*Washington, District of Columbia*

L. H. ADAMS, *Director*

In the summer of 1941 the first step was taken toward setting up a comprehensive program of defense research centered at the Geophysical Laboratory and under the auspices of the National Defense Research Committee of the Office of Scientific Research and Development. Previously, different members of the scientific staff had accepted problems presented for solution by various governmental agencies, but the regular scientific work was proceeding without major disturbance. The new undertaking was of a magnitude which appeared to require all the Laboratory's facilities and personnel. At the start some time was required for collecting information from military and other sources and for delineating the various lines of research and development. Several of the staff members turned immediately to the new assignment; others proceeded as rapidly as possible to round out those parts of the current researches that were nearing completion, preparatory to laying their customary work aside for the duration of the emergency. During this transition period there was opportunity to put the finishing touches on several investigations and to prepare them for publication. It is fortunate that without hindering the preparations for our present program of developing new devices for offense and defense, the results of a number of researches could be collected and published, and thus even in a small way the continuity of fundamental research in geophysics could be preserved for a while.

Shortly after the declaration of war, all resources of the Laboratory were applied toward war work. With few exceptions,

staff members are now occupied with various parts of the war program undertaken by the Laboratory. These exceptions include one member who is filling an administrative position in a unit of the NDRC, one member on leave of absence who is a civilian employee of the War Department, two on leave of absence who are civilian employees of the Navy Department, and one on leave of absence who is managing a large optical glass plant. Despite the urgent need at the Laboratory for experienced investigators, it appeared that these persons were rather uniquely qualified for their respective special tasks, and it was judged that in these capacities their services would contribute best to the war effort. The regular staff has been supplemented by about thirty temporary employees, including physicists, mathematicians, chemists, technicians, and stenographers.

Although almost all the work has been on a single unified program in the interest of the war effort, two or three smaller assignments have been accepted and carried forward under contract. For the main undertaking the Geophysical Laboratory functions not only in the performance of a contract for research and development between the Institution and the OSRD, according to which the Institution is reimbursed for the cost of new equipment and additional personnel; the Laboratory is also the focus of a still larger program involving a dozen or more contracts with universities, institutions, and commercial organizations. The Director of the Laboratory is the chairman of a unit in the NDRC, and by virtue of this governmental appointment is primarily responsible for



initiating and carrying forward the program as a whole. An office of this governmental unit is maintained at the Geophysical Laboratory, and for the handling of the official administrative business two full-time Civil Service employees are stationed there.

The following is a summary of the regular work completed and published during the past twelve months. Inasmuch as most of the investigations have been referred to in previous annual reports, it will perhaps suffice merely to present the abstracts of individual papers.

### SUMMARY OF PUBLISHED WORK

- (1051) Bradleyite, a new mineral, sodium phosphate—magnesium carbonate. Joseph J. Fahey. (With X-ray analysis by George Tunell.) *Amer. Mineralogist*, vol. 26, pp. 646-650 (1941).

A new anisotropic fine-grained mineral, associated with shortite and carbonaceous clay, was found in the drill core of the John Hay Jr. Well No. 1 in Sweetwater County, Wyoming, at a depth of 1342 feet 10 inches, by Mr. Fahey, of the Geological Survey, U. S. Department of the Interior, Washington, D. C. It has been named bradleyite in honor of Dr. W. H. Bradley, of the Geological Survey. Chemical analysis shows that the formula is  $\text{Na}_3\text{PO}_4 \cdot \text{MgCO}_3$ . X-ray powder diffraction photographs of bradleyite were made by Dr. Tunell, of the Geophysical Laboratory, with filtered copper K radiation and show that it does not contain  $\text{MgCO}_3$  in the form of magnesite. The spacings and intensities of the X-ray powder photograph of bradleyite are tabulated to aid in its future identification.

- (1052) Introduction to symposium on "Reactions and equilibria in chemical systems under high pressure" (*Amer. Chem. Soc.*). R. E. Gibson. *Chem. Revs.*, vol. 29, pp. 439-445 (1941).

From a detached thermodynamic point of view it may seem surprising that studies of the effects of temperature and of composition variations should so far have outrun studies of the effects of pressure, because the three variables—pressure, temperature, and composition—are of coordinate thermodynamic importance in determining the state of a chemical system. The purpose of this sym-

posium is to take cognizance of the fact that interest in the behavior of chemical systems under pressure changes has increased in the past decade, and to consider some recent advances that have been made. By way of introduction to the papers given in the symposium, attention is called to six general fields in the study of material systems under high pressure that are of interest to chemists, as follows: (1) the displacement of equilibria in homogeneous systems under high pressure; (2) the displacement of equilibria in heterogeneous systems; (3) acceleration or retardation of chemical reactions by pressure; (4) new phenomena; (5) knowledge of the behavior of naturally occurring substances under extreme conditions; (6) new methods of attacking old problems.

In order to illustrate the place of the various types of high-pressure investigation in the general scheme of physical chemistry and to answer the still frequent question "What do P—V—T measurements have to do with chemistry?" a chart showing the interrelations among the various activities is given.

- (1053) Equilibrium in heterogeneous systems at high temperatures and pressures. L. H. Adams. Symposium on "Reactions and equilibria in chemical systems under high pressure" (*Amer. Chem. Soc.*). *Chem. Revs.*, vol. 29, pp. 447-459 (1941).

Following a summary of the principles involved in chemical equilibria, there is given a brief discussion of apparatus and experimental procedure for investigations in this field. Special attention is paid to systems that include a solid phase. The effects of pressure and of temperature are considered separately

and in combination. A résumé is presented of certain experimental results obtained at pressures extending to several thousand atmospheres and at temperatures exceeding  $1000^{\circ}$  C. Reference is made to the application of these results to manufacturing processes and also to volcanology and other branches of geophysics.

- (1054) Radioactivity of ocean sediments. IV: The radium content of sediments of the Cayman Trough. C. S. Piggot and Wm. D. Urry. *Amer. Jour. Sci.*, vol. 240, pp. 1-12 (1942).

The radioelements in the uppermost layers of the sediments at the bottom of the ocean are not in equilibrium, and a study of the relations that exist in material of uniform character, lying under very deep water, is of fundamental importance in any interpretation of more complex sediments, such as are produced under areas of intermittent glaciation or other disturbing influences. Therefore material from a great ocean deep situated in middle latitudes is of special value. The Cayman Trough, lying south of Cuba, and including the Bartlett Deep, is a peculiarly satisfactory location for such studies. Here the water is almost stationary and the biologic environment has remained quite uniform for a long time. Among the many radioactive elements, uranium, ionium, and radium have sufficiently long lives to be of special importance in such studies. A history of these three elements is reflected in the variation of the radium content of ocean sediments with depth below the ocean floor. Measurements of this variation demonstrate that the concentrations of uranium, ionium, and radium at any given time are established by the usual laws of radioactivity governing the growth and decay of radioelements in a system that is not in radioactive equilibrium. The experimental results must be adjusted to the condition of the sample in the undisturbed sediment. This requires a knowledge of the history of the specimens, from the time when the sediment was taken by the core sampler to the time at which the specimens were analyzed. The relation between radium

content and depth in a given ocean sediment promises a method of determining the rate of accumulation of the deposit at that place.

- (1055) Melting and transformation temperatures of mineral and allied substances. F. C. Kracek. Section 11 of Special Papers No. 36, *Geol. Soc. Amer.*, "Handbook of physical constants," ed. Francis Birch, pp. 139-174 (1942).

This is a critical compilation of melting points and other characteristic temperatures for minerals and mineral-like artificial compounds and other substances which may be of interest to the worker in geological sciences. Data are given for the individual compounds, and for binary and higher mixtures of such compounds, so far as they are known. The material is arranged under the following headings: elements; oxides; hydrous and hydrated oxides; binary aluminates; binary borates; binary oxide systems; three or more oxides (except  $\text{SiO}_2$ ); binary silicates; ternary and higher silicate systems (except systems with  $\text{Al}_2\text{O}_3$  and  $\text{B}_2\text{O}_3$ ); aluminosilicates; borosilicates; miscellaneous systems containing silicates; hydrothermal alteration of silicates and other minerals; carbonates; sulfates; oxygen salts; haloids; sulfide-type minerals; ternary sulfides. The aim in compiling the tables has been to describe the known thermal reactions of the compounds and the systems briefly, but in enough detail to be of use to an investigator not only in the laboratory but also in the field, where extensive reference books are usually not available.

- (1056) Effect of pressure on phase equilibria in binary condensed systems. R. E. Gibson. Section 13 of Special Papers No. 36, *Geol. Soc. Amer.*, "Handbook of physical constants," ed. Francis Birch, pp. 187-202 (1942).

Although very few data on the effect of pressure on binary systems of direct geological interest are available, a variety of chemical systems have been studied experimentally over ranges of pressure and temperature, and these systems are sufficiently varied to give a general picture of the types of effect that may

be expected. The compilation is not exhaustive, but an attempt has been made to include all the different types of behavior that have been observed, and a list of references is appended with a notation of the contents of the papers cited. The following headings show the scope of the compilation: I. Binary condensed systems containing water: (a) effects of relatively low pressures on the solubility of salts in water at constant temperature; (b) effects of high pressures on the solubility of solids in water; (c) effect of pressure on the temperature of the incongruent melting of hydrates. II. Binary condensed systems composed of organic compounds: (a) pressure—solubility relations at constant temperature; (b) effect of pressure on the eutectic temperature and composition; (c) miscellaneous examples.

- (1057) Temperature — pressure — volume and phase relations of water. Roy W. Goranson. Section 14 of Special Papers No. 36, Geol. Soc. Amer., "Handbook of physical constants," ed. Francis Birch, pp. 203-212 (1942).

In this compilation are presented tables of the most probable values for the specific volume of water in various forms over a considerable range of temperature and at pressures up to 1200 bars. Included also is information on: the volume change associated with various transformation points; the heats of vaporization and heat capacity of water; the equilibrium pressures and temperatures at the several triple points; and data for the various equilibrium curves including melting curves.

- (1058) Heat capacity; heat of fusion. Roy W. Goranson. Section 16 of Special Papers No. 36, Geol. Soc. Amer., "Handbook of physical constants," ed. Francis Birch, pp. 223-242 (1942).

The existing information on the heat capacity of minerals and rocks and the heats of fusion and transformation is tabulated in convenient form. The heat capacities are calculated in terms of the true or instantaneous values over a range of temperatures ex-

tending in many instances from  $-200$  to  $1200^{\circ}$  C. Full literature references are given.

- (1059) Radioactivity of ocean sediments. V: Concentrations of the radio-elements and their significance in Red clay. Wm. D. Urry and C. S. Piggot. Amer. Jour. Sci., vol. 240, pp. 93-103 (1942).

The relationship between the radioelements uranium, ionium, and radium in those deep-sea deposits known as "Red clay" is similar to that previously described for the calcareous sediments of the ocean. The Red clay, represented by a core 246 cm long, is distinguished from the calcareous sediments by a very rapid decrease in the radium content just below the surface of the ocean bottom, and by the attainment of the final equilibrium between the above three radioelements in the bottom quarter of the core, which signifies a very slow deposition as compared with that of the calcareous deposits. The radium content at equilibrium with the uranium is only 7 per cent of that near the surface of this Red clay deposit. The high surface concentrations of radium and ionium, particularly in Red clay, are therefore only transient phenomena, produced by some unknown mechanism which concentrates these elements, relative to the uranium content, during the deposition of the sediment.

- (1060) Methods and instruments used in mineralogy. F. E. Wright. Amer. Mineralogist, vol. 27, pp. 145-154 (1942).

This paper was delivered before a joint session of the Mineralogical and Geological Societies of America as the address of the retiring president of the Mineralogical Society. It considers briefly a few of the methods and instruments now in use by mineralogists in determining the physical, crystallographical, and chemical properties of minerals. Experience has shown that in experimental work the introduction of a new method or a new instrument may enable the observer to explore fields heretofore inaccessible for lack of the proper weapons of attack. In present war-time surroundings this condition is especially evident, as is also the importance of adequate

supplies of the instruments of warfare and of new methods and weapons of defense and of offense.

In particular, the paper discusses three tools useful to mineralogy—the reflecting goniometer, the petrographic microscope, and X-ray apparatus—for the purpose of illustrating how progress in mineralogy has been dependent on the availability of suitable methods and instruments of attack; and how an instrument useful in one branch of science may prove to be equally serviceable in another field, if properly adapted to meet the conditions imposed in the new field.

(1061) The radio-elements in non-equilibrium systems. Wm. D. Urry. *Amer. Jour. Sci.*, vol. 240, pp. 426-436 (1942).

In an isolated system in which the radio-elements are not in equilibrium, the relative amounts of the members of a radioactive series are established by time only. Such a system exists in the uppermost sediments of the ocean bottom, and the relative amounts of uranium, ionium, and radium have been determined in a number of core samples of such ocean-bottom deposits. In order to assign time intervals to these sediments, an equation was needed, but the general equation could not be found in the literature, although special cases for simple initial conditions have been treated. The general equation has now been developed. Its derivation assumes no particular initial amounts of the various members of a radioactive series.

(1062) The system  $\text{CaO}-\text{FeO}-\text{Al}_2\text{O}_3-\text{SiO}_2$ . I: Results of quenching experiments on five joins. J. F. Schairer. *Jour. Amer. Ceram. Soc.*, vol. 25, pp. 241-274 (1942).

A study of the quaternary system  $\text{CaO}-\text{FeO}-\text{Al}_2\text{O}_3-\text{SiO}_2$  was undertaken in order to obtain information about the mutual melting relations of pyroxenes, pyroxenoids, olivines, and melilites—four important groups of rock-forming minerals—and to acquire specific knowledge of their chemical compositions. Each of these mineral groups involves extensive solid solutions.

In this preliminary paper, liquidus data are presented for five planes within a regular tetrahedron used to represent the phase relations in the quaternary system. These five planes were chosen to explore that portion of the tetrahedron containing compositions of interest to igneous petrology.

The results of quenching experiments on 216 separate compositions are given. Liquidus data are complete for five joins through the tetrahedron:  $\text{SiO}_2$ —anorthite— $\text{FeO}$ , anorthite— $\text{Al}_2\text{O}_3$ — $\text{FeO}$ ,  $\text{CaSiO}_3$ —anorthite— $\text{FeO}$ , gehlenite—anorthite— $\text{FeO}$ , and  $\text{CaSiO}_3$ —gehlenite— $\text{FeO}$ .

Although data are given for only five joins, it has been shown how these data indicate within approximate limits the temperatures and compositions of eleven quaternary invariant points and show the direction of change of composition of the liquid phase during crystallization in a large portion of the tetrahedron.

An equilibrium diagram for the ternary system  $\text{FeO}-\text{Al}_2\text{O}_3-\text{SiO}_2$  is given, but the data on which it is based will be published in a separate paper.

Much information on the coexistence of solid phases is presented, and the approximate composition of the liquid phase throughout the crystallization process may be followed.

The application of these results to refractories and slags of interest in ceramics and metallurgy is briefly discussed.

(1063) Time relations in ocean sediments. C. S. Piggot and Wm. D. Urry. *Bull. Geol. Soc. Amer.*, vol. 53, pp. 1187-1210 (1942).

Nonequilibrium between the radioactive elements in the surface of the ocean bottom provides a method of measuring intervals of time in the past 300,000 years. The well preserved geological and biological history of the ocean basins has been worked out by others for many of the cores of ocean sediments obtained by Piggot, and the above method of measuring time intervals in years has been applied to these cores. The results indicate that the effects of glaciation on the

continents are contemporaneous with equivalent effects on the type of deposit in the ocean bottom; that the effects of glaciation on the type of ocean sediment are widespread, extending in the northern hemisphere at least to the Caribbean Sea; and that within short intervals of time there is in the ocean bottom a considerable variation, attributable directly or indirectly to climatic changes, which, probably because of the continuous effacement of the evidence on land, has not been reported in studies of continental glaciation.

This method cannot compete in accuracy with the use of the annual varved clays for measuring very recent intervals of time, but it has the advantages of (1) application to a considerable area of the earth's surface; (2) reference to the present time; and (3) applicability to at least half of the Pleistocene epoch.

The rate of deposition of ocean sediments is treated as a subsidiary problem. The obvious step from the determination of time intervals in a core to the rate of deposition of the sediment represented by the core is complicated by the present incomplete knowledge of the distortion of the sediment in the process of obtaining the sample. The average rates of deposition agree with estimates by other methods, some of which, however, are open to the same criticism. There is apparently considerable variation in the rate of deposition of ocean sediments in the past, but the data can be only qualitative at present because of the above complication.

- (1064) Pyrrhotite; melting relations and composition. Einar Jensen. *Amer. Jour. Sci.*, vol. 240, pp. 695-709 (1942).

The melting relations of pyrrhotite and adjoining portions of the system FeS—Fe were studied by means of the differential heating-cooling-curve method. The mixtures were sealed in specially designed silica glass containers to prevent oxidation and loss of sulfur at high temperatures. A preparation corresponding to the formula FeS melts over a large temperature interval with dissociation into a solid richer in sulfur and a liquid richer in iron. Increasing sulfur

raises the melting temperatures to a maximum where the composition  $\text{Fe}_{12}\text{S}_{18}$  melts sharply like a simple compound. Mixtures with more iron than FeS show eutectic melting. A diagram has been made showing these melting relations, and other relations at lower temperatures taken from the literature.

- (1065) Origin of shapes of quartz sand grains. Earl Ingerson and Joseph L. Ramisch. *Amer. Mineralogist*, vol. 27, pp. 595-606 (1942).

The quartz grains in many metamorphic rocks tend to be elongate parallel to the c-axis. Recently a similar elongation has been observed in the quartz grains of unmetamorphosed sandstones; also another elongation parallel to the unit rhombohedron. Current explanations ascribe these elongations to fractures parallel to these directions and differential abrasion during transport. To check these explanations, three sets of experiments were carried out, with the following results: (1) There was a decided tendency for some samples of quartz to fracture parallel to the unit rhombohedron, but no sample showed a pronounced fracture parallel to the c-axis. (2) Quartz grains from weathered (but undisturbed) quartzose igneous and metamorphic rocks show a tendency to be elongate parallel to prism and unit rhombohedral faces. (3) Abrasion tests on oriented prisms show that quartz is harder on prism faces than normal thereto. It is concluded that the elongation of quartz sand grains is due to original shape rather than to fracture and differential abrasion during transport.

- (1066) A method for the summation of the Fourier series used in the X-ray analysis of crystal structure. A. L. Patterson and George Tunell. *Amer. Mineralogist*, vol. 27, pp. 655-678 (1942).

In recent years there has been a very widespread use of the Fourier series in the analysis of the data obtained by the diffraction of X-rays in crystals. The electron density in a crystal can be represented by a three-dimensional Fourier series in which the coefficients

are the structure factors  $F(hkl)$ , the intensities of the diffraction lines, corrected for certain known trigonometric factors, being proportional to  $|F(hkl)|^2$ . The projection of the electron density on a plane perpendicular to a zone axis can be represented by a two-dimensional series using only the  $F$ 's of the diffractions in that zone. Various methods leading to the successful analysis of X-ray data have been devised which depend on the summation of Fourier series. Routine methods for carrying out the summation of such series have become part of the necessary equipment of any laboratory specializing in X-ray analysis.

This paper describes in detail a method that has proved useful in the summation of one-dimensional Fourier series, and a procedure that enables this method to be applied to the summation of two-dimensional series such as those by which the electron density of a crystal is represented as a function of the coordinates in the projection of the unit cell on a particular plane. The method, like those of Robertson and of Lipson and Beevers, utilizes cardboard strips, each carrying a series of values of a certain trigonometric function, but differs from the other two in that the selection of numbers to be added from a series of strips for a given point of the unit cell is accomplished by one of a set of stencils, the strips being laid on a rack in the order of the Miller indices of the corresponding crystal planes, and the stencil being laid over the assembly of strips. The stencils are placed over the assembly of strips one at a time in serial order, and the calculated results, in the summation of the two-dimensional series, then give the electron densities along one line of points in the projection. Repetition of this process with the next assembly of strips yields the electron densities along the next line of points. Experience has shown that this method is well adapted to the range of  $F$ -values (or of  $|F|^2$ -values) from 0 to 1000.

(1067) Apparatus for direct measurement of linear structures. Earl Ingerson. *Amer. Mineralogist*, vol. 27, pp. 721-725 (1942).

Modern methods of metamorphic and igneous geology frequently require that large

numbers of linear elements be measured in the field. Under many circumstances this is a difficult and time-consuming operation with the ordinary compasses in use for geologic surveying.

A piece of apparatus has been devised that can save much time in taking a series of lineation measurements, since only a single placing is required for each measurement. It consists of a compass mounted with a graduated semicircle weighted so that it remains vertical; the compass is provided with a weighted pointer which keeps it horizontal. This arrangement is swung on pivots in a frame having a straight edge that can be placed on, or parallel to, a linear structure in the field. Direction of pitch is read on the compass and angle of pitch is read on the vertical circle.

The apparatus can be used on overhanging surfaces and on outcrops where no planar structure is apparent just as well as on the more commonly encountered type of outcrop. Also, dip and strike can be determined by measuring the dip just as a lineation is measured, and taking the direction normal to the pitch as the strike of the planar structure.

(1068) The binary system  $\text{CaSiO}_3$ —diopside and the relations between  $\text{CaSiO}_3$  and akermanite. J. F. Schairer and N. L. Bowen. *Amer. Jour. Sci.*, vol. 240, pp. 725-742 (1942).

The system  $\text{CaSiO}_3$ —diopside is the type of binary system involving both solid solution and enantiotropism. The temperature of the inversion of wollastonite ( $\beta\text{CaSiO}_3$ ) to pseudowollastonite ( $\alpha\text{CaSiO}_3$ ) is raised by solid solution of diopside in wollastonite, and in compositions between 0 and 21 per cent diopside there is an inversion interval. In fact, the inversion temperature is raised so much (from  $1125^\circ$  to  $1368^\circ \text{C}$ ) that wollastonite solid solutions actually appear on the liquidus. There is little or no solid solution of diopside in pseudowollastonite. There is a eutectic at  $1358 \pm 2^\circ \text{C}$  and at 62 weight per cent diopside. At the eutectic, crystals of pure diopside and of wollastonite solid solution with the maximum amount of diopside (22 per cent) are in equilibrium with

liquid. No  $\text{CaSiO}_3$  enters into solid solution in diopside crystals. At temperatures below the eutectic, wollastonite solid solution crystals contain less diopside than at the eutectic, and crystals formed at higher temperatures therefore show the phenomenon of unmixing at lower temperatures.

The system  $\text{CaSiO}_3$ —akermanite shows the simple eutectic type of melting diagram with the eutectic between pseudowollastonite and akermanite at  $1400 \pm 2^\circ \text{C}$  and at 57 weight per cent akermanite. There is no solid solution of akermanite in either wollastonite or pseudowollastonite. The system is binary at all temperatures at which liquid is present, but because of the instability of akermanite at temperatures below about  $1325^\circ \text{C}$ , the system ceases to be binary in certain compositions and at certain temperatures.

The relations between the metasilicate molecules present in pyroxenes and the related pyroxenoids are briefly discussed, and the lack of mutual solid solubility between pyroxenoids and melilites is pointed out.

(1069) The system  $\text{CaSiO}_3$ —diopside—anorthite. E. F. Osborn. *Amer. Jour. Sci.*, vol. 240, pp. 751–788 (1942).

The plane  $\text{CaSiO}_3$ —diopside—anorthite occupies an important position within that part of the quaternary system  $\text{CaO}$ — $\text{MgO}$ —

$\text{Al}_2\text{O}_3$ — $\text{SiO}_2$  of interest to the geologist. New data are presented for compositions lying in this plane, and the phase relations are discussed with the aid of a series of diagrams. A ternary reaction point is present at  $1245^\circ \text{C}$ , and the lowest temperature at which liquid exists in the system under equilibrium conditions is  $1236^\circ$ . The alleged compound  $5\text{CaO} \cdot 2\text{MgO} \cdot 6\text{SiO}_2$  does not appear in the system, as formerly believed. Data are presented supporting the evidence of Schairer and Bowen that this compound does not exist. The crystals of diopside appearing in the system are slightly aluminous. Consequently, the system is not completely ternary. Some additional data are presented for the limiting systems  $\text{CaSiO}_3$ —anorthite and diopside— $\text{anorthite}$ .

(1070) Glass. George W. Morey. In *Rogers' Manual of industrial chemistry*, 6th ed., chap. 20, pp. 775–813. New York, D. Van Nostrand Co. (1942). (No separates available for distribution.)

The subjects of this section of the revised edition of the book are treated under the following subheads: historical, definition and structure, composition, properties, manufacture, products, and economics of glasses.

(1071) Annual Report for 1941–1942.

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# DEPARTMENT OF TERRESTRIAL MAGNETISM

*Washington, District of Columbia*

JOHN A. FLEMING, *Director*

## SUMMARY

The progress of geophysical research in which international collaboration plays an important part has been further retarded during the report-year, July 1, 1941 to June 30, 1942, by the extension of the war in which all the great powers of the Earth have become involved. Studies of terrestrial magnetism and electricity have not escaped the disastrous effects of this crisis. Field-operations of the Department, which have been one of the international aspects of the regular program, have had to be abandoned until the return of normal intercourse among nations. Fortunately, magnetic surveys by organizations and individuals in many countries have offset in some degree the inadequacy of data caused by this curtailment. Fortunately, also, there are many observatories situated in regions not affected as yet by military operations which are able to continue their recordings and compilations of data on the progress of secular changes, so necessary in keeping isomagnetic charts current for purposes of navigation and surveys in the air and on land and sea.

The widespread demands for application to the war effort of the results of past and present investigations have again emphasized the practical value of the many aspects of the Department's researches in Earth physics. Many of the facilities of personnel, laboratory, shop, and buildings, at Washington and at the observatories, were deflected to investigations and solutions of war problems. A number of the staff were assigned upon request to special duties elsewhere. Thus there has been possible only

a somewhat limited continuation of the regular program; nevertheless, it is possible to include in this report a considerable amount of worth-while development. Many items of scientific value were developed in the investigation of special war problems.

In conformity with the action of the Trustees, the services of the regular scientific and administrative personnel and the use of facilities have been contributed without charge to the government. These services by the 89 budgeted scientific and administrative staff members during the report-year included nearly 36,400 hours and over 6200 hours, respectively, for the two groups; the corresponding totals for the whole period of the emergency since 1940 were 56,400 and 11,200 hours. On June 30, 1942, ten of the regular and temporary personnel were on leave of absence. To assist in the development of urgent projects for the Army and Navy and other governmental agencies, a number of contracts at cost without overhead were undertaken. The peak number of additional investigators engaged on account of these contracts during the year, including physicists, engineers, technicians, and administrative assistants—many through the generous action of universities and industrial organizations in granting leaves of absence for the emergency—was 211.

## REVIEW OF YEAR'S PROGRESS

*Measures of geomagnetic activity.* Reports on the three-hour-range indices of geomagnetic activity were received for the

calendar year 1940 from 25 observatories, that is, 18 in addition to the 5 in the United States of the Coast and Geodetic Survey, and 2 of the Institution in Peru and Western Australia. The disruptions caused by the war have reduced the total number of observatories reporting these indices during 1941 to 19. It is possible, however, to give partial effect to the resolution adopted in 1939 by the International Association of Terrestrial Magnetism and Electricity, according to which the three-hour-range indices were to replace from 1940 the numerical characterization of days previously used. The Department has tabulated, summarized, and published the values supplied.

*Geomagnetic investigations.* Average values of the disturbance of daily variation, storm-time variation, solar daily variation, daily means of disturbance, and non-cyclic change for international disturbed and quiet days were derived. Tables of post-perturbation and annual variation for the period 1905-1937 were completed. Derivations for the equator were made of the storm-time and disturbance daily variations day by day for the same period. These new data are at present being used in the reduction to epoch of the extensive magnetic measurements by the Department on land and sea. The Department's isoporic charts for the epoch 1920-1925 were redrawn, and results for the region of the Pacific Ocean incorporated therein; use was made of consistency-tests suggested by Chapman in obtaining improved estimates of secular change. An attempt is also being made to obtain, by analytic continuation, improved estimates of measures of the Earth's magnetism in high latitudes from the better-determined values in low and middle latitudes.

The probability of ranges in the magnetic elements greater than various assigned magnitudes was estimated for any

latitude, and the probabilities per day of magnetic storms of various intensities were deduced. A study of methods of prediction of fluctuations in geophysical phenomena from observed changes in the past was continued.

Electric current-systems of bays and the annual variation were deduced. The investigation of the relations of geomagnetic with solar and other cosmic data was continued. Attempts to forecast geomagnetic and ionospheric conditions several days in advance were inaugurated and fair success was attained.

*Terrestrial electricity.* Ionization-meters were designed, constructed, and tested for use in a more precise investigation of the question whether the amount of radioactive matter in the Earth, measured in recent years by other methods, is adequate to account for the rate at which ions are formed in the air over land by agencies other than cosmic radiation.

Nuclei of condensation, entities which serve as starters in the formation of water-drops and also affect the electrical state of the atmosphere, were further investigated, with special regard to their nature, the sources of supply, the manner of dissemination, and the rate of loss from the atmosphere. The technique of counting these nuclei was also critically studied and decisions were reached on some disputed points.

Investigations of atmospheric-electric phenomena registered at the Institution's observatories (Watheroo in Western Australia and Huancayo in Peru) indicate rather clearly that at Watheroo, during both day and night, nuclei introduced into the atmosphere from sources on the Earth are disseminated throughout a stratum extending from the Earth to a height of at least 1 km; at Huancayo, where nuclei are in much greater concentration than at Watheroo, they are also distributed in a

stratum to a height of about 1.5 km during daytime, but at night in the dry season a shallow stratum of stable air often forms and in this the concentration of nuclei diminishes during the night to less than one-tenth the concentration in daytime. There are corresponding large changes in the atmospheric-electric elements.

Attention was given to a number of practical problems, chiefly in aeronautics, which touch some branch of atmospheric electricity or associated subjects.

*Ionosphere.* Three complete automatic ionospheric recorders were in continuous operation in the field at the Watheroo, Huancayo, and College observatories. All reductions and tabulations were kept current and promptly forwarded. Extended analyses of the ionospheric data were confined to practical applications of value to the war effort.

Interpretations of ionospheric reactions during magnetic storms were continued. Accumulating evidence indicates a post-perturbation effect which may be worldwide in nature. Following several of the magnetic disturbances, simultaneous rapid decreases of electron-density in the  $F_2$ -region were recorded both at Huancayo and at Watheroo. The trend of recovery and the time of reaching normal conditions at both stations appear to be closely related.

Developmental and experimental work was likewise confined largely to wartime applications. Tests of the automatic camera for the recording of aurora were completed under actual operating conditions at temperatures down to  $-20^\circ$  F. The constant-voltage controllers were forwarded to Huancayo and Watheroo following testing and adjustment at the Washington office.

The Department's policy of full cooperation with government agencies and with qualified representatives of allied govern-

ments was continued and expanded. Several papers dealing with ionospheric characteristics and related phenomena including radio wave-propagation were prepared. The technique of measurement of intensity of the Earth's magnetic field in the ionosphere which was applied to observations at Huancayo may introduce an important new field of research linking ionospheric and geomagnetic analyses even more closely than at present.

*Nuclear physics.* Some progress was made in improved functioning of the pressure electrostatic generator in the Atomic-Physics Observatory, but reasonable expectations of 4 to 5 million electron-volts on the tube for this generator are not yet attained.

Although slowed down by lack of personnel and difficulties in obtaining materials and appurtenances, the 60-inch cyclotron installation was so well advanced that satisfactory tests of magnet and vacuum-system (including pumps, valves, vacuum-chamber, and radio-frequency electrode housing) could be made. The vacuum-pressure was lower than  $5 \times 10^{-6}$  mm of mercury. The magnet was found to produce a field greater than 17,000 gauss. In terms of probable deuteron-beam energy, this field promises an upper limit of about 27 million electron-volts—considerably more than there was reason to expect from experience elsewhere.

The advantages of the use of this equipment for producing artificially radioactivated materials for investigations in chemistry, biology, and physics are obvious. The cooperation of the National Cancer Institute was most helpful, especially so as that organization continued the assignment of Physicist D. B. Cowie, of its staff, to this project; in the absence of the regular staff of physicists of the Department, he and the technicians working with him are

to be credited with a large measure of the progress made.

*Observatory- and field-work.* In collaboration with the University of Alaska, the Observatory at College was maintained and magnetic and auroral programs were initiated early in the report-year. The Huancaayo and Watheroo magnetic observatories continued extensive geophysical observations as heretofore. Cooperation at Apia in atmospheric electricity was concluded December 31, 1941. The recordings of the atmospheric-electric elements and earth-currents in cooperation with the United States Coast and Geodetic Survey and Bell Laboratories at the Tucson Observatory were continued, as was the maintenance of international magnetic standards at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey. Constant contact with the Division of Geomagnetism and Seismology of the Survey has been mutually advantageous, the more so now that the Survey is undertaking extensive reoccupations of CIW and other stations in South and Central America.

To complete the geomagnetic and auroral compilations and discussions of the United States Antarctic Expedition of 1940-1941, the facilities of the Department were extended, at the request of the United States Department of the Interior, for the whole year to R. G. Fitzsimmons and for five months to M. A. Wiener, of that Expedition.

Cooperative work was continued with surveys in Africa, Australia, and New Zealand and at observatories in South Africa, Samoa, Greenland, and Mauritius through the loan of CIW instruments, supplying of materials, and preparation of instructions.

*Miscellaneous.* Two of the retired members of the staff, who had contributed largely to the operations of the Department, have died. Carroll Christopher Ennis died November 24, 1941, after an enviable record of service to geomagnetism and oceanography. William John Peters, who was largely responsible for the successful development of the Institution's extensive surveys at sea on the *Galilee* and the *Carnegie* and for many geomagnetic investigations, died July 10, 1942, just after the close of the report-year. Both these men were unique in their scholarly qualifications and devoted unselfish service to science.

The Department was fortunate in having on active duty three others of its retired staff—J. W. Green, A. Smith, and W. F. Wallis—who did much to carry on as replacements for younger men assigned to war problems.

Although the bibliography accompanying this report shows fewer publications than during the preceding year, it gives ample evidence of the wide range of the activities of the staff.

## INVESTIGATIONAL AND EXPERIMENTAL WORK

### TERRESTRIAL MAGNETISM

Those of the staff chiefly engaged at Washington on investigational and experimental work relating particularly to geomagnetism were Fleming, J. W. Green, Johnston, Miss Lange, McNish, Scott, Torseson, Vestine, Wallis, and Wells. Chap-

man at London gave constructive advice and made theoretical investigations which have proved of great value to the Department's program. A considerable portion of the time of each, in some cases almost all, was given to work on special analyses and

compilations and on instruments concerned with the war effort. The following statements regarding the several items of investigation summarize only a part of the work actually done.

#### PERMANENT FIELD

*Analysis of geomagnetic field.* The investigation of methods of field-analysis and use of computing-machines to facilitate such analysis were continued by Vestine. To conclude the project of field-analyses by integrals on the theoretical side, an attempt was made to obtain a more compact expression for a function giving external current-systems corresponding to any observed magnetic field at the Earth's surface. Two methods previously worked out give a complete and exact solution but are rather slow in application. This function is intimately associated with the height of electric current-systems above the Earth compatible with observed surface fields.

A study was made of the world-wide distribution of magnetic anomalies. Large anomalies appear in volcanic regions, where rocks such as granite and basalt, magnetized on cooling below the Curie-point, are likely to be common, and consequently also in earthquake-zones. A collection was also made of material and charts showing locations of ferromagnetic mineral deposits, where magnetic anomalies may be expected.

*Reduction of field-data to mean epochs.* The construction of new world isoporic charts for the epoch 1930-1935 was continued and preliminary steps were taken to construct similar charts for the epoch 1940-1945. Geomagnetic charts of the present epoch show large systematic errors, and the new isoporic charts should assist materially in providing the more accurate rates of secular change needed for their improvement and the best use of the avail-

able material. The isoporic charts developed at the Department by Fisk for the epoch 1920-1925 were replotted on Mercator's projection and tested for mutual consistency in the case of the isopors for horizontal intensity and declination. For declination, this method is being used in obtaining a compromise between the results of Fisk and Duvall for the region of the Pacific Ocean. The estimates based on Chapman's modification of Schuster's curl-method (see p. 44) show marked evidence of inconsistencies, and the problem of adjustment of the isopors so that the results for horizontal intensity and declination will be mutually consistent is being studied.

Tables to correct field-observations for post-perturbation and annual variation were prepared for all days of the period 1905-1937. Since disturbances vary both in number and in intensity with time of year, they contribute the major part of an apparent annual variation. This variation throughout low and middle latitudes is most marked in the geomagnetic north component, for which it has an amplitude of the order of about 10 gammas ( $1\gamma = 0.00001$  CGS unit).

The annual variation was derived using data for about 65 observatories of the Polar Year, 1932-1933. The results proved satisfactory for the geomagnetic north and east components, but were highly erratic for the vertical component except in high latitudes. A similar derivation was made for a period of 24 years for 10 stations in low and middle latitudes; the results for the vertical component were again found to be somewhat erratic. The geomagnetic north component is small near the geomagnetic poles and increases rapidly equatorward to a maximum at the auroral zone. Just outside the auroral zone this component diminishes rapidly with decreasing

latitude and attains a secondary maximum near the equator. The geomagnetic east component was found to be small in all latitudes. The vertical component is largest near the center of the auroral zone and zero near the equator, where a reversal in sign occurs.

The annual variation can be separated into two parts. One part is symmetrical about the equator with a minimum near the equinoxes, and varies with latitude in proportion to the annual average of disturbance in amplitude. Cynk showed that the remaining part is nearly sinusoidal in character with a period of one year, with minimum at the winter solstice and maximum at the summer solstice. The annual variation thus comprises both an annual and a seasonal component.

The annual variation varies in amplitude with sunspot-cycle, the amplitude for years of sunspot-maximum being about twice that for years of sunspot-minimum.

A possible electric current-system of the part symmetrical about the equator closely resembles that corresponding to the annual average of the daily means of disturbance, if the lines of current-flow are assumed to flow in closed circuits in a thin layer in the Earth's atmosphere at constant height. Lines of current flow from east to west in all latitudes, with maximum concentration of current in polar regions. In the case of the sinusoidal part, the current-lines are roughly along parallels of geomagnetic latitude opposite in direction in the Northern and Southern hemispheres, and increase in intensity from zero near the equator to a maximum in polar regions, where the variation with time of year is marked. This notable seasonal variation also gives rise to considerable distortion in the average current-system of geomagnetic disturbance.

The development of methods for the reduction of field-observations to mean of

day on a world-wide scale was continued. For this purpose the solar daily variation ( $S_q$ ), disturbance daily variation ( $S_D$ ), storm-time variation ( $D_{st}$ ), and irregular disturbances ( $D_i$ ) are being derived for individual days. Using estimates based on graphs for two and three stations spaced roughly  $120^\circ$  and  $180^\circ$  apart in longitude in equatorial regions, the means according to hour of Greenwich time appear to give a rather good estimate of the storm-time variation. The estimated corrections in the case of  $S_D$  are less satisfactorily determined. In the case of  $S_q$  use is being made of average values corrected in amplitude for sunspot-variation, and for daily variability by inspection of magnetograms at one station.

*Mathematical treatment of geomagnetic charts.* Chapman continued his discussions of isomagnetic charts, embodying his results in three additional papers. They dealt with the following subjects: "Earth-air electric currents and the mutual consistency of  $H$  and  $D$  isomagnetic charts"; "Mathematical notes on isoporic charts and their singular points"; "The mutual consistency of the declination and horizontal-intensity isoporic charts." These discussions and the methods proposed have already proved most useful in the revision of isomagnetic and isoporic charts with that greater accuracy required for more recent epochs and for use in analyzing the permanent field.

#### MAGNETIC DISTURBANCES AND COSMIC RELATIONS

A study was made of the frequency and current-systems of geomagnetic bays, using extensive data of the Second International Polar Year, 1932-1933. The daily and annual frequencies of bays were examined for groups of stations in four different latitude-zones: (I) near the geomagnetic north

pole; (II) the auroral zone; (III) middle latitudes; and (IV) the equator. The new results show that bays appear with about equal average frequency at all times of day, the apparent marked variations in frequency with local geomagnetic time found in zones II to IV being occasioned by a notable variation in the amplitude of bays with time of day. In all latitudes bays appear with an average amplitude greater at the equinoxes than at the solstices.

Heights of the polar part of the electric current-system of bays were estimated in two different ways, for two simple assumed forms or models. The heights obtained agreed well with previous, though less detailed, results of Birkeland, Goldie, Vestine and Chapman, and McNish, and place the probable location near the *E*-region of the ionosphere.

An approximation to the average current-system of bays was deduced, assuming the currents to be confined to a spherical shell concentric with the Earth, at a height of 150 km, and using averaged vector-changes of many bays taken for time of maximum. This current-system differs from that proposed for magnetic storms by Chapman, and subsequently considered by Goldie and Vestine, in that there appears little evidence of a storm-time part ( $D_{st}$ ); the current-system resembles that for the diurnally varying component ( $S_D$ ) of storms, though notably distorted in polar regions. In these regions important seasonal changes in the current-distribution were also found in individual bays. This simple current-system was found to afford a fairly satisfactory possible explanation, both qualitative and quantitative, of the world-wide incidence of bays in frequency and amplitude.

Investigations by Wells of relations between the four major magnetic disturbances of 1941 and 1942 (March 1, July 4-5, and September 18, 1941, and March 1,

1942) and ionospheric changes are summarized on pages 56-57. Data for the great magnetic storms of the present sun-spot-cycle were tabulated and discussed by McNish.

In cooperation with five astronomical observatories (Navy, Mount Wilson, McMath-Hulbert, Climax of Harvard University, and Whitin of Wellesley College) and with geophysical observatories of the Institution and others in Australia, Canada, and New Zealand, more intensive research on the correlation of solar, ionospheric, and geomagnetic disturbances was begun. There has already been developed a means of forecasting, with fair success, ionospheric and magnetic disturbances for four to five days in advance. The results of these investigations are being closely coordinated with the effects on radio conditions, in cooperation with the National Bureau of Standards.

The experimental investigation of the upper atmosphere using modulated searchlight beams, reported upon last year (Year Book No. 40, pp. 66-68), had to be deferred because all the personnel engaged on it were on leave of absence in connection with war efforts. Meanwhile the searchlights and associated equipment have been properly housed at the Kensington and Washington stations.

*Cosmic-ray investigations.* On behalf of the Institution's Committee on Coordination of Cosmic-Ray Investigations, the necessary attention (Lange, Forbush, and Fleming) was given to the maintenance of CIW precision cosmic-ray meters at five observatories. Because of leave of absence for war work, Forbush could devote only a small amount of time to the compilation and discussion of records obtained; greater responsibility had therefore to be taken by Miss Lange in these matters. A notable disturbance was that coincident with the magnetic storm of March



1, 1942, which was reported upon by Miss Lange and Forbush, V. F. Hess, and others. The report of the Committee (Year Book No. 41, pp. 87-102) briefly abstracts the results of this study and others.

#### ARCHIVES OF MAGNETIC RECORDS

The microfilm copies of records acquired during the Second International Polar Year, 1932-1933, have again proved of great value, especially in the improvement of isomagnetic charts required for military use.

Ennis began a complete revision of annual values of the geomagnetic elements as given in publications and reports of the world's observatories. Following his death, this compilation was completed by Scott. The lists show the observed and computed annual values at over 100 principal existing and discontinued observatories for declination, inclination, and horizontal, north-south, east-west, vertical, and total components of the Earth's field. These values will supply investigators with the published magnetic results as well as with computed values of such of the elements as are not included in the publications. In the case of some of the observatories—fortunately not many—there was evidence of a lack of accuracy in the computational or observational work; every effort was made to correct such errors of computation and to check the derivation of those of the seven elements and components which must depend upon the three elements usually recorded, that is, declination, horizontal intensity, and inclination,

or declination, horizontal intensity, and vertical intensity.

#### INSTRUMENTAL DEVELOPMENTS

*Electromagnetic standard.* Analysis of the absolute measurements, completely checked by Wallis and Scott this year, on the electromagnetic standard (see Year Book No. 40, p. 68) shows that the diameter of the coil is known to  $\frac{1}{2}$  part in a million ( $0.5 \times 10^{-6}$ ) and that the coil-lengths are correct to  $1\frac{1}{2}$  parts in a million ( $1.5 \times 10^{-6}$ ). The pitch of the coils varies less than  $\pm 2$  microns. The temperature-coefficient was determined to be approximately 5 parts in a million ( $5 \times 10^{-6}$ ) per degree centigrade. On the basis of these measurements, the absolute value of the vertical component of the Earth's magnetic field at the Cheltenham Magnetic Observatory, where the instrument, when completed, is to be installed as the standard of intensity, will be known to 0.5 gamma and the horizontal component to 0.3 gamma. The assembly of the instrument must of necessity be deferred until personnel and shop facilities can be released from their present war duties.

*New magnetometer design.* The development of new and simple instruments for field-observations reported last year (see Year Book No. 40, p. 68) is being actively continued.

*Automatic auroral camera.* As reported on page 77 of this report, the automatic auroral camera was completed and is functioning quite satisfactorily at the College Observatory in Alaska.

#### TERRESTRIAL ELECTRICITY

Research in terrestrial electricity was considerably reduced because of demands made upon the staff by the war effort. In geoelectricity, the data obtained at the ob-

servatories were examined only to the extent required to ascertain that a high standard of reliability is being maintained; in atmospheric electricity, aside from routine

checks and the reduction of data, some investigations were made by Gish, Sherman, and Wait, and the investigation of condensation-nuclei was continued throughout the report-year by Research Assistant Marcella Lindeman Phillips. Rooney and Torreson were engaged throughout the year on war projects, and all other members of the section devoted varying proportions of their effort to such matters. Some results from this endeavor, in addition to their primary bearing on practical affairs, have interest for geophysics.

#### ATMOSPHERIC ELECTRICITY

*Electrical state of the atmosphere.* An electrical charge in a portion of the atmosphere or the charge on a raindrop is dispersed or lost at a rate depending on the amount of charge and the electrical conductivity of air. The electrical state of the atmosphere is also related in other ways to the electrical conductivity of the air, which in turn depends on the presence of ions, small electrically charged "particles." When the latter are driven by electrical or other forces they effect a transport of electricity. The rate of transportation is proportional to the number of carriers, or ions, their velocity, and the load (electrical charge) borne by each carrier. The load is apparently the same for practically all the carriers, namely, one elementary unit of electric charge. The velocity, however, varies widely. It depends of course on the driving force (electric field-strength or potential-gradient), but also on the nature of the ions, chiefly their size. The "small ions" in the air near the Earth have a size equivalent to that of a few molecules, and attain velocities between 1 and 2 cm per second when in an electric field of 1 volt per cm, but with the same driving force the "large ions," equivalent in size to about a million simple molecules, attain a ve-

locity of only a few ten-thousandths cm per second. Since each of these large ions usually carries the same amount of charge as a small ion, the large ions can contribute comparatively little to the transport of electricity through the air unless their number is very great as compared with that of the small ions. Though usually negligible in this respect, the large ions, or rather the entities (nuclei of condensation) from which they are formed, play an important role in atmospheric electricity because they are usually formed from the nuclei of condensation at the expense of small ions. Thus an increase in the concentration of large ions entails a decrease in the concentration of small ions and a nearly corresponding decrease in the electrical conductivity of air.

The conductivity of the atmosphere also depends on the rate at which small ions are formed. The principal recognized ion-forming agents in the air near the Earth are the cosmic radiation and radiations from radioactive matter in the Earth and in the atmosphere.

The foregoing considerations suggested investigations of the following subjects: (a) the nuclei of condensation; (b) the sources from which these nuclei come; (c) how they are disseminated in the atmosphere; (d) how they are finally lost; and (e) the rate of formation of small ions in the atmosphere by radiations from radioactive matter in the Earth. Other investigations included analyses and interpretations of various aspects of the registrations, obtained at the Institution's magnetic observatories, of the several atmospheric-electric elements.

*Rate of ion-formation.* Because of the following observed facts, it has been questioned whether the rate of ion-formation by known ionizing agents is adequate to account for the number of small ions in the lower atmosphere. (a) The rate of

ion-formation inside chambers with thick walls (3-mm brass) is several times greater than that to be expected on the basis of the values reported by Evans and Goodman for the radioactive material in rocks. (b) The variation of this rate with time, in either thin- or thick-walled chambers, shows differences with respect to character and amplitude which would hardly be inferred from available information regarding the kind and quantity of radioactive matter in the Earth (Gish). General plans for the solution of the problem which results from (a) were described by Hess (*Terrestrial Magnetism*, vol. 46, pp. 409-415, 1941). The apparatus designed by Gish for use with a null method was constructed in the instrument-shop of the Department, precise determinations of the constants were made by Sherman, and a preliminary investigation of the general performance of the equipment was made by Gish and Sherman. The chief results of the latter are: (a) Contact-potentials are entirely negligible; (b) the rate of ionization from a known amount of radium is in satisfactory agreement with values found by others with comparable equipment; (c) in a laboratory room a rate of ionization of 6.8 ion-pairs per cubic centimeter per second was found; (d) there appears to be no appreciable amount of radioactive matter in the material (brass) from which the ionization-chambers are made—a favorable but unexpected circumstance; (e) ionization by secondary radiation, of low penetrating power, excited in the walls of the chamber by gamma radiation is apparently revealed by this method of investigation when the chambers are exposed to the radiations from a specimen of radium, but no such effect is definitely indicated by exposure to the radiation from the radioactive matter normally present in the walls, etc., of the room. Further investigation is re-

quired to ascertain the extent to which this result must be taken into account in the final interpretation. These ionization-meters are to be used by Hess and associates at Fordham University to ascertain whether the low values recently reported for the radioactive content of rocks and other earth-materials can be verified by this method.

*Sources of condensation-nuclei.* Many nuclei are supplied to the air by boiling water; their number increases rapidly from the time when bubbles begin to rise (Gish, Sherman, Phillips). The steam-plume from a tea-kettle contains many more water-droplets than the number of nuclei normally present in air. This increase is probably due partly to the breaking of water-films—nuclei are formed when water and other liquids are atomized.

Nuclei are produced in abundance when drops of water fall upon a hot metal surface. Metal while being heated below incandescence gives off nuclei for a few minutes, provided this property has not been destroyed by heating some days previously.

Nuclei, at least such as can be detected with an Aitken nuclei-counter, are not given off from the undisturbed surface of most liquids at normal temperature and pressure. When these liquids are atomized, however, an appreciable number of nuclei are produced. Nuclei may be formed from the molecules of various vapors by sufficient sudden cooling. When the latter occurs, the concentration is sometimes so great, and consequently the size of the drops formed in the counter so small, that nuclei thus produced may escape detection. Earlier observations (Wait) indicated that nuclei are numerous in exhaled air, but current observations (Phillips) failed to confirm this. No explanation for these divergent results was found.

*Dissemination of condensation-nuclei.*

The dissemination of condensation-nuclei in the air obviously depends chiefly on the motion and mixing of the air. Specific information about the rate and manner of dissemination in a closed room was required for an investigation of the rate at which nuclei are lost from the air. The rate of dissemination was found (Phillips) to be such that in the quiescent air of a closed bedroom the nuclei became uniformly distributed from floor to ceiling in about one-half hour after introduction from an atomizer or other source; no evidence was found of a distribution of nuclei in strata such as has been reported by Landsberg.

The rate of loss of nuclei from the air or the rate of decrease in the number of nuclei in the air may be attributed to either or both of the following processes: (a) Nuclei may coalesce and form larger entities which settle out of the air; (b) they may reach the Earth's surface or the walls of rooms, etc., simply by diffusion, and adhere to the surface of these. The rate of diminution in the concentration of nuclei should be proportional to the square of the concentration in the first case and simply proportional to the concentration in the second case. If both these processes are active, the diminution may at the start, when the concentration is large, vary more nearly as the square, and later as the first power of the concentration. This tendency was evident in a fair proportion of the series of observations (Phillips) made in closed rooms, and in chambers of much smaller volume, using nuclei from different sources. The diminution, however, was found to depend to some extent on the nature of the nuclei, that is, on the source of supply. The diminution-rate is greater for nuclei formed from the more volatile liquids, and those produced by "condensation upon molecules" appear to be less stable than others.

*Method of counting nuclei.* The method of counting nuclei received some further attention (Gish, Phillips). The claim has been made that the small ions in the air are "counted" in the Aitken pocket nuclei-counter. Further evidence against this claim was obtained in an experiment designed for another purpose, namely, to ascertain whether in the air there are nuclei of different classes with respect to their effectiveness in condensation. In order to form a droplet about a nucleus, the air in the counting chamber (saturated with water-vapor) is suddenly expanded and consequently cooled. Less expansion (a smaller ratio of expanded volume to initial volume) should be required for nuclei which have a greater than for those which have a smaller affinity for water. Within the range of expansions (expansion-ratios 1.05 to 1.35) obtainable without modifying the counter, the total number of droplets which could be precipitated from a sample of room air containing nuclei did not vary significantly; that is, all entities which serve as nuclei of condensation in this counter can be precipitated by very little expansion, or very little supersaturation, of the air. It is therefore concluded that all these entities are about equally effective as condensation-nuclei and that small ions are not counted. All nuclei are not precipitated, however, by the first expansion of a sample; about 60 per cent of those present just before an expansion are precipitated when an expansion-ratio of 1.30 is used, and about 40 per cent for an expansion-ratio of 1.05 (at average room temperature). But if the sample is expanded repeatedly until no more droplets are formed, the total number of droplets obtained from comparable samples apparently does not depend on the expansion-ratio. This finding supports the view that repeated expansions are required in order to remove all nuclei and that the sum of

the droplets counted in these expansions is the best measure of the concentration of nuclei. In the normal practice with this type of counter, when the largest expansion-ratio (1.35) is used, five successive expansions are required to precipitate 99 per cent of the nuclei; but for the smallest expansion-ratio used in these experiments (1.06), ten expansions are required to precipitate the same proportion of the nuclei. Obviously the tedium of counting is reduced by using the larger expansion-ratio. Little further improvement in this direction could be realized, however, by providing the counter with a longer pump, thus making larger expansion-ratios available, because the stage where condensation on small ions sets in is apparently reached when expansion-ratios slightly greater than that now available are used.

*Modifications in atmospheric-electric elements caused by condensation-nuclei.* Condensation-nuclei in the atmosphere at the Huancayo Magnetic Observatory effect extraordinary modifications in the atmospheric-electric phenomena observed there. This was first inferred from a study (Gish, Year Book No. 37, p. 15) of the registrations made at that Observatory of the atmospheric-electric and meteorological elements. The three important modifications of the electrical phenomena are: (a) The measured electric current, which flows from air to Earth, is certainly less than one-half that which would be expected at such a high altitude (11,000 feet). (b) The contribution by negative ions to the electric conductivity of air at night is often greater than that by positive ions at this place, whereas the contribution by positive ions usually is the greater at other places. (c) The diurnal variation of potential-gradient and of air-conductivity is remarkable for the large and abrupt change (four- to five-fold) which occurs between 06<sup>h</sup> and 08<sup>h</sup> almost daily during the dry season.

A tentative explanation of these features proposed by Gish is briefly as follows: Regular observations (counts) of nuclei at 08<sup>h</sup> each day had shown that the nuclei-concentration is much greater than is to be expected, considering the immediate environment of the Observatory. Hence the nuclei are thought to come from a distant source and to be carried by the more general air-circulation. They are introduced into the air near the surface at the Observatory by turbulent stirring (eddy-diffusion) when that process is active. When the lower air becomes stable, however, which is most likely at night, turbulent mixing of this with the higher stratum becomes less effective, and the rate at which nuclei are supplied to the lower air is reduced. Then the nuclei-concentration near the surface decreases and the air-conductivity increases. In the morning after sunrise, when the air in the lowest stratum becomes sufficiently heated, mixing of the lower with the higher overrunning air sets in and nuclei are again supplied to the surface-air from above. The ensuing increase in nuclei-concentration entails a decrease in air-conductivity. If the stable lower stratum which develops at night is shallow (say 100 meters), and the nuclei-concentration in the general circulation does not vary from night to day, the electrical resistance of a vertical air-column from the Earth to a height of some tens of kilometers is modified very little by the change in conductivity from night to day. Hence only a very small corresponding change in air-earth current is to be expected and the potential-gradient should vary inversely as the conductivity. The recorded data are in accord with these expectations.

The relation between values of negative and positive conductivity observed at night (the former exceeding the latter) is a simple consequence of the decrease of total

conductivity with altitude in the air near the Earth's surface. This observation also indicates that the lower stratum extends to a comparatively small height. Rough estimates, by two independent methods, had indicated that it is probably not less than 10 meters nor more than 100 meters.

The height to which the variation of conductivity at the surface extends was estimated (Wait) during the present year by a more extensive examination of the electric data. Not only was the low value previously estimated for the height of the lowest nighttime stratum verified by this examination, but it was also found that the average diurnal changes in air-conductivity at this place are confined to a shallow stratum.

On 15 days in August 1941 special observations of the nuclei-concentration were made (Jones, Ledig) at the Huancayo Magnetic Observatory at 06<sup>h</sup> and 07<sup>h</sup> in addition to the regular observations at 08<sup>h</sup>, in order to ascertain whether nuclei are as scarce at night as is implied by the proposed explanation outlined above. These observations show a contrast in nuclei-concentration considerably greater than that in conductivity. The average count of nuclei at 08<sup>h</sup> was 10.9 times that at 06<sup>h</sup>, whereas the average conductivity at 06<sup>h</sup> was 3.6 times that at 08<sup>h</sup>. The proportional change in concentration of nuclei is larger, as compared with that in conductivity, than is usually found at other places, but studies of the regular nuclei-counts at 08<sup>h</sup> at Huancayo (Gish, Torreson, Year Book No. 38, pp. 74-75) revealed a comparable tendency in the variations from day to day. Such a tendency may arise in several ways. The one which now seems most plausible (Gish) is that the nuclei in the lower air at night are of different character from those present in daytime. The former, perhaps chiefly of local origin, "combine" more readily with the small

ions in the air than do the latter, which doubtless come from a very different distant source. The rate of combination between the small ions and the nuclei from the distant source appears to be notably smaller than in any other case thus far reported. In brief, these early-morning observations of nuclei have not only corroborated the proposed explanation for three outstanding aspects of atmospheric electricity at Huancayo, but have also shed light upon some other matters, for example the rate of combination between nuclei and small ions.

Condensation-nuclei in the atmosphere at the Watheroo Magnetic Observatory modify the atmospheric-electric elements in a manner different from that at Huancayo, but no less interesting. This fact was brought out more clearly than heretofore by analyses made by Wait.

The method of analysis is based upon the fact that nuclei and some other agents generally affect the electric state of the atmosphere to a much greater degree over land than over sea. Accordingly the atmospheric-electric data obtained on cruises of the *Carnegie* have frequently been used as a standard for comparison with other data. These studies have indicated the desirability of making a more precise comparison using data observed simultaneously on land and at sea.

Material for such a comparison was obtained at the Watheroo Magnetic Observatory and on board the *Carnegie* during 1928-1929. Thus far the data for 42 fair-weather days in November-December 1928 and January-February 1929 have been compared (Wait). Of these 42 days, 17 are classed as "smoky" and 25 as "non-smoky" at Watheroo. The concentration of nuclei is of course much greater on days in the first than on days in the second category, hence the terms "smoky" and "non-smoky" connote a relatively large

and a relatively small concentration of nuclei, respectively.

The essential features of the data for potential-gradient and for air-earth current are conveniently expressed by the Fourier series,  $y = \bar{y} + \sum (a_n \cos n\theta + b_n \sin n\theta)$ , where  $\theta$  in degrees is 15 times the time in hours counted from Greenwich midnight. The coefficients of the first four harmonics are listed in table 1.

the latter method, but the diurnal variation of these values obtained by the former was of about the same character as that for values obtained by the latter method. The average was 4 per cent lower for non-smoky and 14 per cent lower for smoky days; ranges 0 to 9 and 8 to 25 per cent, respectively.

An inspection of table 1 discloses that, although the mean potential-gradient at

TABLE 1

COMPARISON OF FOURIER COEFFICIENTS FOR POTENTIAL-GRADIENT ( $X$ ) IN VOLTS PER METER AND AIR-EARTH CURRENT ( $i$ ) IN  $10^{-7}$  ESU AT SEA AND AT WATHEROO MAGNETIC OBSERVATORY

CONDITION AT WATHEROO	ELE- MENT	MEAN	FOURIER COEFFICIENTS								GMT MAXI- MUM (h)	RATIO* (c <sub>2</sub> /c <sub>1</sub> )
			24-hr.		12-hr.		8-hr.		6-hr.			
			a <sub>1</sub>	b <sub>1</sub>	a <sub>2</sub>	b <sub>2</sub>	a <sub>3</sub>	b <sub>3</sub>	a <sub>4</sub>	b <sub>4</sub>		
AT SEA, Carnegie												
Smoky.....	X..	146	- 8.9	-22.5	-5.2	-0.9	-1.2	-1.6	+1.7	+1.9	16.6	0.22
	i...	9.7	- 0.48	- 1.62	-0.44	-0.10	-0.04	-0.05	+0.16	+0.04	16.8	0.26
Non-smoky..	X..	130	- 7.7	-22.9	-7.0	-1.8	-0.4	-2.0	0.0	+1.2	16.8	0.30
	i...	8.8	- 0.51	- 1.57	-0.46	-0.14	-0.01	-0.14	-0.01	+0.06	16.9	0.29
ON LAND, WATHEROO MAGNETIC OBSERVATORY												
Smoky.....	X..	123	- 8.7	-33.8	-6.7	-7.2	-5.4	-3.8	+1.9	+1.9	17.0	0.28
	i...	9.1	+ 0.33	- 0.29	+0.02	+0.16	+0.05	-0.37	0.00	+0.08	21.3	0.37
Non-smoky..	X..	89	-13.6	-14.9	-2.3	+1.4	+1.6	-2.9	+1.2	-0.6	15.2	0.13
	i...	8.6	- 0.14	- 1.07	-0.20	+0.20	+0.11	-0.12	-0.03	0.00	17.5	0.26

\* Ratio of amplitudes ( $c_2/c_1$ ) =  $(\sqrt{a_2^2 + b_2^2} / \sqrt{a_1^2 + b_1^2})$ .

The values used for air-earth current in this analysis are the products of corresponding individual values of potential-gradient and of total air-conductivity, not the products of corresponding mean values. The importance of calculating values of air-earth current in this way was again emphasized (Year Book No. 40, p. 76) by a comparison of the values calculated both ways with data for 108 days at Watheroo. Nearly all values calculated by the former, more exact but more tedious, method were lower than those obtained by

sea was significantly greater than at Watheroo on both classes of days, the mean air-earth current-density was nearly the same at the two places. On smoky days the character of the diurnal variation of current differs between land and sea more than that for other corresponding elements—the maximum for the 24-hour harmonic occurs 4.5 hours later on land than at sea and this component is less prominent. Some of the other differences, however, are also significant. These differences are revealed more clearly, and in a form more

susceptible of interpretation, by an examination of the diurnal variation in the ratio of air-earth current at sea to air-earth current on land for corresponding hours.

The electrical resistance of a vertical column of air of  $1 \text{ cm}^2$  cross-section, extending upward from the Earth to the level of great conductivity (some tens of kilometers), is directly proportional to the ratio of air-earth current at sea to that on land. This "columnar resistance" has a definite daily period, being smaller in daytime than at night and essentially of the same character as that determined previously from nonsimultaneous data on land and at sea (Year Book No. 40, p. 77).

The average columnar resistance on smoky days is greater than that on non-smoky days, but the minima are nearly equal; thus the difference on the two types of day occurs chiefly at night. The data for the nine Februaries from 1926 to 1934 show an average resistance 20 per cent greater for smoky than for non-smoky days: the minimum excess on smoky days was 11 per cent and the maximum 30 per cent.

An explanation (Wait) of the variation in columnar resistance at Watheroo on smoky days is that smoke, and the associated condensation-nuclei, are introduced into the atmosphere principally at night and dispersed to a height sufficient to increase the columnar resistance and reduce the air-earth current, as observed. Smoke occurs almost exclusively in the summer months (November to February) and at night. This agrees with the observed responses in the registrations of potential-gradient and air-conductivity. Days in summer on which smoke is observed do not differ appreciably from those without noticeable smoke in respect to wind-velocity, wind-direction, or air-temperature. Disturbances caused by smoke hamper investigations of the more general

aspects of atmospheric electricity, but reveal several features of geophysical interest.

The height to which smoke of local origin rises at Watheroo on the average summer day can be estimated roughly from the change in columnar resistance, assuming that the air-conductivity as affected by smoke is uniform from the Earth's surface up to a definite height. The height thus estimated (Wait) from simultaneous observations on land and at sea for smoky days is 1.5 km, and the height estimated from the much more extensive data for Februaries of 1926-1934 is 1.0 km. For non-smoky days the estimated effective height of the nuclei-bearing layer is 1.6 km for both groups, and there is no evidence of appreciable changes during the day. By the method used in estimating the effective height of the nuclei-bearing lower stratum, estimates are also obtained for the part contributed to the columnar resistance by atmosphere above that height. The point of interest in the latter is that that portion of the columnar resistance is apparently the same on smoky as on non-smoky days and is also essentially the same as that for the corresponding region of the atmosphere derived by Gish and Sherman from air-conductivity data registered on the stratosphere flight in November 1935. This indicates that the air above the estimated effective height is not usually contaminated by nuclei coming from the Earth. The conclusions are: (a) that, on the average, at Watheroo nuclei arising from the Earth are distributed throughout a layer of air extending from the Earth upward to an effective height of at least 1 km, and generally not beyond this; (b) that this height does not vary much during the day; and (c) that it is about the same on smoky as on non-smoky days. The last conclusion is consistent with the observation, already men-



tioned, that smoky and non-smoky days, on the average, have the same meteorological characteristics.

The question of dissemination of nuclei by wind at Watheroo is apparently clarified by results obtained from a statistical examination (Wait) of potential-gradient and wind-velocity data for the months of January, February, and March 1926-1934: (a) On non-smoky days the average potential-gradient increases from 87 volts per meter for zero wind-velocity to 105 volts per meter for a wind-velocity of 5 miles per hour, and for higher velocities there is little further change in potential-gradient; (b) on smoky days the average potential-gradient increases from 217 volts per meter for zero velocity to a maximum of 225 volts per meter for a velocity of 2 miles per hour, and then gradually diminishes to about 180 volts per meter for a velocity of 12 miles per hour. The concentration of nuclei doubtless varies in a similar manner. The interpretations are: (a) that on days of both classes nuclei are brought into the more immediate vicinity of the Observatory by wind, but in greater concentration on smoky days than on non-smoky days; (b) that the source of the nuclei on non-

smoky days is probably more distant and spread over a wider area than that for smoky days; (c) that the source of the nuclei for smoky days is confined to a limited area which is probably not many miles from the Observatory. The last is consistent with the observation that most of the smoke noticed at Watheroo comes from bush-fires. Some wind is required to bring smoke to the Observatory, but since wind-turbulence increases with wind-velocity, the smoke is dispersed more rapidly at the higher wind-velocities. Under the joint action of these two factors the density of smoke (or concentration of nuclei) at the Observatory may be expected to increase with wind-velocity for low velocities, reach a maximum, and then decrease with further increase of velocity.

*Cooperation and consultation.* On the occasions of several visits at the Department and through correspondence, members of the staff profited from stimulating discussions of current problems with Professor Victor F. Hess, of Fordham University. Gish served on the Subcommittee on Lightning Hazards to Aircraft of the National Advisory Committee for Aeronautics.

## INVESTIGATIONS OF THE IONOSPHERE AND ITS RELATION TO PROBLEMS OF GEOMAGNETISM

The external part of the Earth's magnetic field arises from electric current-systems which probably circulate in the ionosphere. Detailed and accurate knowledge of ionospheric characteristics therefore provides a basis for extending and evaluating analyses of the external part of the Earth's magnetic field.

Early theoretical work by Gauss, which was later extended by Stewart and Schuster, required current-systems in the Earth's outer atmosphere to explain certain observed variations in geomagnetism. It was

argued that such current-systems could arise in highly ionized regions far above the Earth. Years later, when Marconi performed his famous demonstration of long-distance radio communication between England and Newfoundland, Kennelly and Heaviside independently proposed that radio waves are reflected back to Earth by a highly ionized region or layer in our outer atmosphere. Here we have the first link between geomagnetism and radio wave-propagation through their mutual dependence upon the ionosphere.

The original experimental determination of the ionosphere was made in 1925 by Breit and Tuve, of the Department of Terrestrial Magnetism, with the generous assistance of Taylor at the Naval Research Laboratory. They developed the pulse-and-echo technique which is now widely adopted for ionospheric studies. Simultaneously Appleton and Barnett in England obtained independent evidence of the ionosphere with a wave-interference method. The active interest of the Department in the subsequent development and application of ionospheric research has been maintained largely because of the important contributions to knowledge of the Earth's magnetic field which are made possible by this method of attack.

Radio apparatus provides our only means of exploring the ionosphere, which extends from about 40 to 400 miles above the Earth. Short pulses of radio-frequency energy are transmitted. These signals penetrate through the atmosphere until they encounter concentrations of ions and electrons of sufficient density to bend them around and return them to Earth. The recorder measures time-interval between signal and "echo." This provides values of virtual height of the reflecting region. For example, a signal reflected from a layer 100 km above the Earth travels an overall distance of 200 km, which requires transit time of just two-thirds of one-thousandth of a second (0.00067 sec).

Waves of higher frequency are more penetrating and require greater concentrations of electrons for reflection. Waves of still higher frequencies are not returned to Earth, since the ionosphere does not contain sufficient concentrations of charges to reflect these signals. Complete radio exploration of the ionosphere is accomplished with apparatus which automatically sweeps over a wide range of frequencies and pho-

tographically records the heights of the reflected signals. Equipment for this purpose has been developed by the Department, and the continuous operation of these units in the field is providing a solid foundation for detailed analyses of geomagnetic and related phenomena.

#### FIELD-OPERATIONS

The three complete automatic multi-frequency ionospheric recorders designed and constructed at the Department of Terrestrial Magnetism are now in continuous operation at the Huancayo (Peru) Magnetic Observatory, the Watheroo (Western Australia) Magnetic Observatory, and the College (Alaska) Observatory. This apparatus sweeps through a frequency-range from 16.0 to 0.516 Mc/sec and automatically records the apparent height of ionospheric echoes. One frequency-sweep is completed every 15 minutes. The apparatus consists of transmitter, receiver, control-units, recorder, and power-supplies. Transmitter and receiver are automatically interlocked so that no separate tuning of receiver is necessary. In effect, one variable oscillator is used for both transmitter and receiver.

The normal requirements for power under operating conditions amount to about one kilowatt. At the observatories in Peru and Australia, power is obtained from Diesel generators. These units provide direct current for operation of rotary converters which in turn supply alternating current for the radio apparatus. Each rotary converter is accurately controlled to a frequency of 60 cycles per second by means of a precise tuning-fork. Similar provisions for independent power are made at the College Observatory, although the commercially available power-supply has been found to be generally satisfactory. The installation at each observatory oper-

ated continuously throughout the report-year except for minor interruptions necessary for maintenance and adjustments to the apparatus. The equipment at Huancayo has been operating since November 1937, the recorder at Watheroo since May 1938, and the apparatus at College since June 1941.

#### ANALYSES OF DATA

In general, the results of recordings at each observatory indicate trends which parallel the present downward trend of the cycle of sunspot-activity. The  $E$ -,  $F_1$ -, and  $F_2$ -region critical frequencies at Huancayo and Watheroo observatories are slightly lower than during 1940. This downward trend is expected to continue for another year or two. Analyses show that average annual electron-density of the  $F_2$ -region measured at noon at Huancayo Magnetic Observatory was about 50 per cent greater during the years of maximum numbers of sunspots (1937 and 1938) than during 1941.

Publication of detailed summaries of ionospheric data was discontinued early in 1942. This action was taken following specific request by governmental agencies, in view of important applications of ionospheric data to war problems.

Following is a discussion of ionospheric recordings during several intense magnetic storms:

*March 1, 1941.* The ionospheric conditions during the magnetic storm of March 1, 1941 were discussed in some detail in the last annual report. Further analyses have shown an unusual effect which was not remarked in earlier analyses. Following the conclusion of the severe magnetic disturbance, at about 23<sup>h</sup> 30<sup>m</sup> GMT, March 1, electron-densities in the  $F_2$ -region of the ionosphere decreased very rapidly and simultaneously at both Huancayo and Watheroo. At 05<sup>h</sup> 00<sup>m</sup> GMT, March 2, the  $F_2$ -layer critical frequencies at both locations averaged more

than 5 Mc/sec below the normal mean hourly value. After 05<sup>h</sup> 00<sup>m</sup> a recovery in the direction of normal was noted. This recovery was rather gradual, reaching normal values about 12<sup>h</sup> 00<sup>m</sup> GMT, March 2. Since ionospheric characteristics at widely separated points such as these frequently show no direct relationships, it is felt that an occurrence of this nature is worthy of especial note. The extent of the subnormal ionization recorded at each observatory would seem to preclude any possibility of its being a mere coincidence. This view is substantiated by the facts that the decrease in each case started after the end of the storm, the minimum values were reached simultaneously, and the trends back to normal, as well as the times of reaching normal, were in complete agreement.

*July 4-5, 1941.* It will be recalled that the magnetic storm of July 4-5, 1941 was relatively mild from 03<sup>h</sup> 45<sup>m</sup> GMT, July 4, to about 05<sup>h</sup> 00<sup>m</sup>, July 5. The period of greatest disturbance was recorded between 05<sup>h</sup> 00<sup>m</sup> and 24<sup>h</sup> 00<sup>m</sup>, July 5, the interval around 17<sup>h</sup> 00<sup>m</sup> being the most disturbed. At Huancayo and at Watheroo the ionospheric disturbances during the initial phase of the storm were relatively insignificant. At 05<sup>h</sup> 00<sup>m</sup> GMT, July 5, however, electron-densities at Huancayo took a sharp drop to subnormal values. For the duration of the disturbance electron-densities were far below normal, and it is again interesting to note that the lowest values were recorded several hours after the ending of the magnetic disturbances. Normal conditions were reached about 12 hours after the end of the magnetic storm.

At Watheroo electron-densities jumped to values well above normal at 05<sup>h</sup> 00<sup>m</sup> GMT, July 5, but immediately dropped off and continued at subnormal levels for the period of the disturbance. As at Huancayo, so at Watheroo ionospheric conditions did not return to normal until about 12 hours after the end of the storm. The relative degree of disturbance, however, was much smaller at Watheroo than at Huancayo.

*September 18, 1941.* Detailed comparisons of ionospheric effects at the observatories

during the magnetic storm of September 18-19, 1941 were handicapped to some degree by the severity of the disturbance, which produced complete disappearance of echoes for several hours at Huancayo. In general, the recordings at Huancayo showed extensive oscillations and rapid changes in maximum electron-density of the  $F_2$ -region. These changes were sufficient to produce peaks and troughs above and below normal values. However, the extent of deviation from normal was not considered especially significant on September 18. Probably the most important feature at Huancayo was the recording of abnormally high electron-densities between 12<sup>h</sup> 00<sup>m</sup> and 24<sup>h</sup> 00<sup>m</sup> GMT, September 19. During this interval critical frequencies of the  $F_2$ -region were frequently as great as 4 Mc/sec above the normal value.

At Watheroo ionospheric conditions were not greatly disturbed on September 18 except for a short period around 12<sup>h</sup> 00<sup>m</sup> GMT, when abnormally high electron-densities were recorded. For all of September 19, however,  $F_2$ -region electron-densities were below normal. During the first 9 hours of September 19 critical frequencies were more than 3 Mc/sec lower than average. After the end of the disturbance a downward trend continued for several hours before the recovery-phase. Normal conditions apparently were reached about 8 hours after the end of the storm.

*March 1, 1942.* Preliminary analyses of ionospheric conditions during the moderately severe magnetic disturbance of March 1, 1942 have been undertaken. Unfortunately the records at Huancayo are not complete for the interval, because of maintenance and adjustments to the apparatus. No definite remarks may therefore be made concerning the ionospheric reaction at Huancayo during this disturbance. At Watheroo, however,  $F_2$ -region electron-densities were subnormal prior to the commencement of the storm, at 07<sup>h</sup> 30<sup>m</sup> GMT, March 1. The increase in magnetic disturbance was associated with a rapid increase in electron-density to a peak at about 13<sup>h</sup> 00<sup>m</sup>. This was followed by a gradual downward trend to normal values, which were maintained for the duration of

the storm. The disturbance ended about 05<sup>h</sup> 00<sup>m</sup>, March 2, following which the characteristic drop to low values and the gradual rise back to normal was observed. It will be recalled that this same effect has been noted following other periods of magnetic disturbance. No unusual ionospheric effects were noted which might form a basis for further examination in view of the pronounced decrease in cosmic-ray intensity which was reported (see Year Book No. 41, pp. 94-95).

### RADIO FADE-OUTS

The sudden ionospheric disturbances which produced short-period radio fade-outs at Huancayo and Watheroo during the calendar year 1941 are shown in tables 2 and 3. No significance is attached to the

TABLE 2

FADE-OUT SUMMARY, HUANCAYO MAGNETIC OBSERVATORY, 1941

DATE	75° WEST MERIDIAN TIME OF			MAXIMUM ABSORPTION (Mc/sec)
	Start	End	Maximum	
April 3 . . . . .	h m 10 45	h m 11 30	h m 11 00	*
July 3 . . . . .	11 00	12 15	11 45	*
July 5 . . . . .	10 45	12 15	11 30	*
July 8 . . . . .	10 45	11 45	10 45	*
August 20 . . . .	10 57	12 08	11 53	6.1
October 30 . . .	17 15	18 45	18 00	1.3
December 26	09 49	10 46	10 05	9.5

\* Maximum absorption not reported.

fact that Watheroo recorded nearly twice as many fade-outs as did Huancayo. Magnetic records during these occurrences were examined for unusual pulses or bays, which are frequently associated with the ionospheric disturbances. No significant coincidences were noted during the preliminary investigation. This is probably because most of the fade-outs were relatively mild and many occurred during magnetically disturbed periods, which

mask out the small magnetic effects associated with fade-outs.

TABLE 3

FADE-OUT SUMMARY, WATHEROO MAGNETIC OBSERVATORY, 1941

DATE	120° EAST MERIDIAN TIME OF			MAXIMUM ABSORPTION (Mc/sec)
	Start	End	Maximum	
	h m	h m	h m	
January 30...	12 45	13 45	13 08	4.3
February 28...	07 45	09 30	08 00	4.0
February 28...	17 30	18 15	17 45	>9.0
March 3.....	16 30	17 00	16 40	5.0
July 1.....	12 30	13 55	13 10	2.4
July 2.....	10 25	11 30	10 57	4.8
July 9.....	10 45	11 50	11 40	2.0
August 2.....	08 30	13 00	09 00	2.05
September 15	13 15	14 15	14 00	2.7
September 18	10 15	11 10	10 30— 11 00*	>7.5
September 19	09 30	10 20	09 30— 10 15*	>4.0
September 20	10 30	11 35	10 30— 11 30*	>6.3
September 21	10 30	11 05	10 30— 11 00*	>6.7
September 23	10 00	11 05	10 00— 11 00*	>7.0
November 24	08 45	10 45	09 45	2.1

\* No echoes during this period.

#### DEVELOPMENTAL AND EXPERIMENTAL WORK

Practically all instrumental developments and experimental work were carried out in connection with war work and in cooperation with our armed services.

The automatic camera for recording of aurora at the College Observatory was completed. Tests of this unit at temperatures down to 20° F below zero were conducted in the low-temperature rooms of the National Bureau of Standards. Since installation at College, this recorder has been in continuous operation. Preliminary reports from the Observatory indicate that

high correlation between auroras observed directly overhead and significant ionospheric phenomena may be expected.

The constant-voltage controllers for use at observatories were tested on the main generator at the Department. These units are now in operation at the observatories, and the high degree of constancy of voltage obtained by their use has resulted in improved recording.

#### COOPERATIVE ACTIVITIES

The unique position maintained by this Department as a result of the development and continuous operation of automatic multifrequency ionospheric equipment at several field-stations resulted in numerous requests for ionospheric data from federal agencies and from our allies. Special arrangements to insure the prompt handling and early distribution of such material to authorized agencies were undertaken. The data play an important role in estimates of world-wide ionospheric distribution, knowledge of which is essential in consideration of radio wave-transmission problems.

#### PUBLICATIONS AND PAPERS

The Department was represented at the Winter (1941-1942) Convention of the Institute of Radio Engineers in New York City by Wells, who presented a paper on "Ionospheric investigations at Huancayo Magnetic Observatory (Peru) with application to wave-transmission conditions." Following a brief description of the principle and design of the automatic multifrequency ionospheric equipment developed by the Department, the results of continuous observations at Huancayo were discussed in some detail. These results are representative of average ionospheric conditions in equatorial regions. Such regions play an important part in long-distance

radio communications. Typical variations from day to night conditions, as well as season-to-season changes, were discussed. The effect of such ionospheric changes upon selection of communication-frequencies was also emphasized. Normal recordings and the effect of magnetic disturbances upon the ionosphere were discussed. Methods of development and application of transmission-graphs were demonstrated. Such graphs make possible the conversion of the ionospheric data obtained at vertical incidence into radio wave-propagation information at oblique incidence over various distances. The *E*-layer is capable of supporting radio transmission over distances approaching 1500 miles, and the normal limit of single-hop transmission via the *F*-region is somewhat greater than 2000 miles.

Recordings of the frequency-separation between doubly refracted wave-components in the *F*-region at Huancayo were analyzed in terms of the intensity of the Earth's magnetic field at the level of maximum electron-density in the ionosphere.

A paper entitled "Earth's magnetic field and actual heights in ionosphere" was presented by Wells at the annual meeting of the American Geophysical Union in April 1942. A radio wave propagated into the ionosphere becomes divided into separate wave-components of different polarizations under the influence of the Earth's magnetic field. This is similar to the Zeeman effect observed when an electromagnetic wave is propagated in an ionized medium in the presence of a magnetic field. The separation in frequency between the individual wave-components provides a measure of the intensity of the Earth's magnetic field at the *actual* height in the ionosphere from which the signals are being returned. From separate records at Huancayo of critical frequencies of both ordinary and extraordinary wave-compo-

nents, mean hourly values of the frequency-separation over 4 months were used to obtain mean hourly values of magnetic field-intensity,  $H$ , in the ionosphere at the height of maximum electron-density. A plot of these values reveals a form of diurnal variation for  $H$ . Since  $H$  is measured at the height of maximum electron-density, it must be assumed that the diurnal variation in  $H$ , as observed by this technique, is a result of the change in actual height of the region of maximum electron-density of the ionosphere. Assuming the Earth to be a uniformly magnetized sphere, the variation of  $H$  with height above the Earth may be calculated. This provides means for conversion of values of  $H$  as observed from the ionospheric measurements into terms of actual heights. The diurnal curve obtained is similar to the diurnal curve of ionospheric heights obtained independently by other means. The technique outlined is particularly applicable at the magnetic equator. With specially developed apparatus, probably a single observation could be used to obtain accurate measurement of the intensity of the Earth's magnetic field in the ionosphere.

Wells addressed the Institute of Radio Engineers at Cleveland, July 1, 1942, on "Effect of solar activity on the ionosphere and radio communication." Severe disturbances in the ionosphere are produced by unusual solar activity and in turn directly influence radio communication. Solar flares or sunspot-eruptions have been definitely identified as the origin of short-period radio fade-outs. The ultra-violet radiation associated with the solar flare immediately produces intense ionization in the lower part of the ionosphere, which results in complete absorption of all normal sky-wave radio transmission. Disturbances of this nature seldom last

longer than one hour. The most severe radio disturbances, however, coincide with intense magnetic storms—storms frequently associated with active sunspot-areas. It is generally believed that streams of corpuscles are projected from active sunspots, travel to the Earth in one to four days, and produce magnetic storms, auroral displays, and radio disturbances. The severe disturbances can disrupt normal radio communications for several days and interrupt wired circuits. The effect of

magnetic disturbances on radio communication is more pronounced as the wave-path approaches the higher latitudes. Ionospheric recordings, by both the fixed-frequency and the multifrequency techniques, provide fundamental information regarding the development and effect of such disturbances on radio communications.

Valuable reports, compilations, and summaries of the data obtained from the records made at College were prepared by Bramhall and Seaton.

## MAGNETISM AND ATOMIC PHYSICS

Tuve, Hafstad, Roberts, and Abelson of the nuclear-physics group were assigned during the entire report-year to war-research activities. Until August 1941, Heydenburg, Meyer, and L. Schmidt were engaged full time in improvement of the Atomic-Physics Laboratory, but they were then assigned for most of the time to war work using the one-million-volt generator. G. K. Green was in charge of the development of the cyclotron until March 12, 1942, when he began active duty as lieutenant in the United States Signal Corps. From then on he generously devoted his scant spare time to assuring continuity of the work ably carried on by Cowie (assigned from the National Cancer Institute), who with Ksanda, P. A. Johnson, Buynitzky, and Caherty was engaged on the cyclotron throughout the report-year. These men had the assistance of F. R. Nichols (to September 1941) and McCaw (from October 13, 1941 to June 3, 1942, when he joined the United States Army). The assignment of Research Fellows N. M. Smith, Jr., and J. A. Van Allen to war problems was continuous from July 1, 1941. Despite this depletion of personnel, good progress was made.

### ATOMIC-PHYSICS OBSERVATORY

During the last few months in 1941 and January and February 1942, Meyer and Schmidt spent part time in further construction work on the Atomic-Physics Observatory. The accelerating tube had been removed from the generator in 1940 and an effort was made to boost the voltage on the generator by making certain changes in the design of the supporting column of the high-voltage cap. These changes were found to give no substantial improvement in the voltage, however, and the limit of the generator without the accelerating tube remained at 4.5 million volts.

Tests were made in the spring of 1941 on various accelerating-tube designs in an effort to build a tube that would withstand 4.5 million volts without breakdown. Working with an 8-foot test-section, a design was found using the original tube porcelains which gave an improvement of 50 per cent over the old tube. In July 1941 the construction of the many electrode-parts was begun by Schmidt with part-time help by Meyer. The parts were completed in January 1942, and Meyer and Schmidt then assembled and aligned the tube in the

generator. The ion-source was made ready for a test of the tube with an ion-beam. At this time the upper power-belt-pulley assembly was redesigned to allow the tension of the belt to be more easily adjusted. No difficulty was found in obtaining an ion-beam down the tube, but further work will be necessary in the refinement of the focusing system of the tube before the beam will be usable for precise experiments.

### CYCLOTRON

The main units of the 60-inch cyclotron are (1) the magnet, (2) the main vacuum-system, (3) the control-system, (4) the power-supplies, and (5) the radio-frequency circuits. (See Year Book No. 40, pp. 89-91, for statement regarding the Cyclotron Laboratory and the development of the equipment.)

*Magnet.* Measurements made soon after assembly of the 200-ton Armco magnet showed that the pole-faces were out of parallelism by 0.007 inch. With the squeezing out of the heavy oil-film applied to the machined surfaces of contact of the four top, bottom, and side members, this lack of parallelism is now within the limit set of 0.003 inch. The motor-generator has characteristics that allow exciting the coils, which were built by the General Electric Company for a power-input of 75 kilowatts, to 130 kilowatts. Tests to determine whether use of full capacity of the generator would overheat the coils showed it would be safe to energize them continuously with an input of at least 115 to 120 kilowatts.

Before the vacuum-chamber was installed, a careful search was made to find out if any serious inhomogeneities existed in the pole-pieces. This was done by means of a coil of many turns connected to a

fluxmeter. Within the "ion-working space" of 50-inch diameter any inhomogeneities found in the magnetic field were so small as to make it a question whether they were real or the result of experimental error. Any large blowhole in a pole-piece would produce a hole in the magnetic field which would ruin the various focusing characteristics of the cyclotron and make the attainment of large beam-currents impossible.

A record magnetic test was made to measure the magnetic field at the center of the vacuum-chamber and at several points on a radius up to 68 inches at various values of exciting current. With the full rated current of the generator, 600 amperes, the magnetic field in the center, with the vacuum-chamber in place including its filler-plates, is 17,400 gauss. The fringing-field curve was investigated for four different values of exciting current and has a shape favorable for withdrawing the ion-beam from the dees. Measurements of absolute value of the magnetic field were made with a flip-coil and fluxmeter standardized at the National Bureau of Standards. It was possible to make these measurements with an internal consistency better than 1 part in 500 and with an absolute accuracy of 1 part or less in 200.

For tests of the azimuthal symmetry of the magnetic field, twin flip-coils were constructed in such a way that one coil remains at the center of the magnet, while the other revolves on a constant radius. The two coils are mounted on a common shaft and will be connected in series opposition to the fluxmeter. For proper operation of the cyclotron it is necessary that the field be quite symmetrical azimuthally, this being the main reason for the close mechanical tolerances on the magnet and vacuum-chamber. Any small lack of symmetry can be compensated at least to a



first order by inserting the vacuum-chamber so that it is off center with respect to the magnet-poles. The vacuum-chamber position can be checked very precisely with respect to the pole-pieces, and the necessary position for proper magnetic-field requirements can be and must be reproduced accurately. The water-flow for the magnet was checked and the controlling switches were set so that a flow of 3600 gallons of water per hour is required to close them.

*Main vacuum-system.* The main vacuum-system, which includes the vacuum-chamber, dee-tanks, pumps, and various appurtenances, was completed and thoroughly tested and all leaks were eliminated. The four 8-inch oil-diffusion pumps were found to have a pumping speed of about 2000 liters per second when ordinary Cenco Megavac oil was used. The baffle-systems for these pumps were designed and installed, as well as appropriate vacuum-valves and manifolds. The final test of the brass target-box shows it to be free of leaks.

The various components, including target-box, vacuum-chamber, cones, cylinders, main manifold, pumps, baffles, and valves, after individual tests, were assembled, and, although there were almost 200 separate rubber-gasket seals, a vacuum of  $5 \times 10^{-6}$  mm of mercury was obtained within a few hours.

The system was dismantled following this test, and the main vacuum-chamber was withdrawn from, the magnet for the installation of the liners and for inspection and cleaning before final assembly. The pump-out lead was installed in the bottom of the vacuum-chamber, and assembly of copper-liners, radio-frequency connectors, dees, and dee-capacity compensators is under way.

Before the deflector-dee was designed, the path of an ion in the magnetic field when

subjected to various electrostatic deflections was calculated. By means of the deflector-electrode an intense transverse electrostatic field is set up across the path of an ion emerging from the slot in the deflector-dee. This field gives the ion a radial component of velocity which starts the ion in a path across the fringing-field and allows the ion to enter the target-box, the fixed openings of which must be cleared by the ion if it is to strike the target. With the attainable magnetic field, energies of approximately 25 million electron-volts (MEV) with deuterons and 50 MEV with protons are possible. Solution of the differential equations of the ion-path is difficult because the inherent empirical data cannot be expressed in any simple form. These empirical data are the shape of the fringing-field of the magnet and the strength of the varying electrostatic field of the deflector-electrode. A numerical integration was set up and Miss Lange calculated the points of the ion-path for a deuteron of 21.6 MEV subject to deflector-potentials of 120,000 volts and 150,000 volts. The resulting paths show that it will be feasible to bring out a 21- or 22-MEV deuteron-beam with about 120,000 volts applied to the deflector-electrode. The shape of the wall of the deflector-dee was designed to conform with the curves given by the numerical integration.

*Control-system.* The control-desk and the relay-box on the control-room wall are essentially complete. Minor schematic diagrams of the control-system wiring were made.

*Power-supplies.* The ion-source requires two power-supplies, (1) to light the filament, and (2) to create the arc from the ion-source filament to the ion-source cone. The latter emission-supply was completed. It consists of a three-phase bridge-rectifier in which the power-transformers are pre

ceded by a constant-current network of chokes and condensers; it delivers an essentially constant current independent of load-impedance. The current is varied by switching in condensers. The filament of the ion-source will be powered by a small motor-generator set mounted on top of the magnet.

The deflector-electrode is supplied by an air-insulated voltage-doubler rectifier capable of output-potentials from 0 to 200,000 volts. This complete power-supply was installed in a wire-mesh cage to insure protection of personnel. The test of this unit showed it to be perfect with the exception of a coronal breakdown on the 110,000-volt Westinghouse transformer.

Two power-supplies are required for the radio-frequency system. The first, which is completed, is a single-phase, 3000-volt, 1.25-ampere rectifier to supply the final stage of the exciter. The second, which is in construction, is a 200-kilowatt, three-phase, full-wave bridge-rectifier, utilizing six Federal Telegraph mercury-vapor rectifier-tubes, to furnish power to the plates of the final stage of the oscillators. The plate-transformer for this rectifier was installed in the power-room with a concrete curb cast around it with provision for draining any large leakage of oil from the transformer. A steel rack adjacent to the transformer will contain the rectifier-tubes, their filament-transformers, various protective equipment, and a blower controlled by thermostats.

All the power-supplies are enclosed in protective cages equipped with door switches which automatically disconnect the high voltage when a door is opened. Grounding chains will also be installed so that the output can be grounded by anyone working on the power-supply.

*Radio-frequency system.* The radio-frequency system is designed to have a master-oscillator, controlled by a crystal-driven

circuit or by stable inductance-capacitor circuits, the output of which is to be amplified by several stages of buffer-amplifier equipment driving the final radio-frequency amplifier. The final amplifier of the exciter is a large water-cooled tube to excite the grids of two water-cooled tubes in a push-pull circuit coupled by a transmission-line to the resonant circuit in the main vacuum-system. The filament and grid-supporting structures, anodes, and water-jackets for these tubes were completed. The design of these tubes is along lines suggested by Smith and Ayer, of Radio Corporation of America. Difficulty is being experienced in obtaining satisfactory insulators to support the grid- and filament-structures. These tubes are demountable and may be continuously pumped, so that they can be repaired quickly by installation of spare parts.

It is to be hoped that the instrument can be tuned up initially to produce a 100-microampere beam-current of 21 MEV deuterons. The radiation produced by such a beam is enormous, and will make necessary the installation of water-tanks and frequent radiation-surveys for the protection of personnel operating the cyclotron and occupying other parts of the laboratory.

#### MISCELLANEOUS

The reduced staff and the work of design and construction of the cyclotron prohibited any extended nuclear-physics research or completion of manuscripts on work already done.

Cowie found time, however, to cooperate with Drs. Voegtlin, Thomson, and Johnson, of the National Cancer Institute, in an investigation, still in progress, of chemotherapeutic effects of radioactive arsenic on liver tumors.

Cowie was coauthor with Colonel A. A. de Lorimier, of the Army Medical School,

and Dr. T. N. White, of the National Cancer Institute, of two reports to be published in the *American Journal of Roentgenology*. The titles are as follows: "Radiation hazards during roentgenoscopy," by T. N. White, Dean B. Cowie, and A. A. de Lorimier; "Protective features provided with the U. S. Army field X-ray equipment," by A. A. de Lorimier, Dean B. Cowie, and T. N. White. Cowie attended a meeting of the National Advisory Committee on X-Ray and Radium Protection at the Army Medical Center, Walter Reed Hospital, June 13, 1942, at which these subjects were discussed.

An article on a new type of radiation cell for the manipulation of radium was prepared by Drs. A. H. Dowdy and B. Du Bilier, of the Strong Memorial Hospital of the University of Rochester, and Cowie. This paper was accepted for publication in the *American Journal of Roentgenology*.

#### THEORETICAL-PHYSICS CONFERENCE

The Eighth Annual Washington Conference on Theoretical Physics was held April 23-25, 1942, in Washington, D. C., under the joint auspices of the Carnegie Institution of Washington and the George Washington University. The subject, "The problems of stellar evolution and cosmology," was essentially the further development of discussions at the conference of 1938 on "Problems of stellar energy-sources." There seems hardly any doubt that the so-called "carbon cycle," then proposed by Bethe, actually represents the source of energy for our Sun and for all other stars of the "main sequence" and that the energy-source of the so-called "red giant stars" lies in the thermonuclear reactions of lithium, beryllium, and boron, as was proposed by Gamow and Teller.

The problem of stellar evolution, that is, of changes with time in the observable

characteristics of a star, still presents serious difficulties, particularly in its application to the "red giants." Study of the so-called "shell-model" of a star proposed by Gamow in the 1938 conference was considerably advanced during the last year by Chandrasekhar and Schoenberg, who reported their results at the first session of the Eighth Conference.

On the question of the "mixing-up" process in a stellar interior, Randers reported his calculations of the convection-processes in rotating stars.

The problem of the correlation of various theoretical viewpoints on stellar evolution and the observational facts on the relative abundance of stars of various types was discussed. Shapley gave a general survey of the observational evidence. To correlate the theoretical picture of stellar evolution with the observational material, it is necessary to take into account the stellar population in various parts of the universe.

The second problem of the conference was that of the expanding universe and the related question of the origin of chemical elements during the early stages of the expansion. There is still considerable disagreement among investigators as to whether our universe is an expanding one. Consideration of the several estimates of the age of the universe indicated that the problem of the expanding universe must await more information regarding the evolutionary history of separate nebulae.

Thomas reported his attempt to explain the red-shifts in the spectra of distant light-sources as resulting from the interaction of the traveling light-quanta with the free electrons in interstellar space.

The attempts to explain the observed relative abundance of various chemical elements in the interiors of various stars have followed two different directions. It is suggested: (1) that the present abundance arises from some kind of chemical equi-

librium between various nuclei at certain high temperatures and densities; (2) that the origin of elements is a breaking-up process similar to the recently discovered process of uranium-fission. Both points were discussed and it was agreed that the second view is the more probable. Chandrasekhar reported on the "equilibrium-theory." Some details of a breaking-up process of the heavy fragments of primary nuclear matter which would finally lead to the ordinary nuclei of the known stable elements were discussed by Teller.

During the third day fundamental problems of physical constants and the properties of elementary particles were discussed. Teller criticized Dirac's recently expressed view that the number of elementary particles in the universe and also the value of the gravitational constant are slowly changing with time. Assuming Dirac's hypothesis, he would expect large changes

in the luminosity of the Sun, which is contrary to geological evidence.

Thomas presented his recent attempt to build up a formalism for consistent quantization of the electromagnetic field which would eliminate the difficulties inherent in the infinite self-energy of elementary particles.

Pauli discussed the theory of the "mesotron" on the assumption of zero-spin and concluded that this assumption is not satisfactory.

Twenty-six investigators from fifteen universities and research organizations took part in the conference. Several leading nuclear physicists and astronomers who had also accepted invitations to take part could not do so because of urgent unexpected demands of war problems. (A more detailed account of the conference is published in *Science*, vol. 95, pp. 579-581, 1942.)

## FIELD-WORK AND REDUCTIONS

### LAND MAGNETIC SURVEY

Additional material for the volume in the series of Researches of the Department of Terrestrial Magnetism on "Land Magnetic Survey, observations, 1927-1940" was prepared. The manuscript, by J. W. Green, Fleming, Vestine, and Wallis, is now ready for the preparation of the master copy for publication by the offset method.

Various governmental and private organizations were supplied with tabulations of magnetic data, geographical positions and descriptions of stations, and local maps for Africa, Australia, New Zealand, the Pacific islands, Central America, North America, South America, and the polar regions. Revisions were made of the computations of results obtained in the field by the United States Antarctic Expedition of 1940-1941 and the Louise A. Boyd Arctic Expedition of 1941.

The Department cooperated, through the loan of field-instruments and equipment to six observatories, to magnetic surveys in South Australia, Northern Australia, New Zealand, British East Africa, and the United States, as well as to the Boyd Arctic Expedition. International magnetic standards and corrections thereto for field-instruments were maintained as heretofore in cooperation with the United States Coast and Geodetic Survey at the Cheltenham Magnetic Observatory, where CIW sine-galvanometer 1 and CIW Schultze earth-inductor 48 are used as instruments to control these standards.

### FIELD-OPERATIONS AND COOPERATIVE SURVEYS

*Africa.* Dr. A. Walter, Director of the British East African Meteorological Service, using

CIW magnetometer and inductor 13, continued active cooperation with the Department. In addition to the occupation of stations reported previously, he secured repeat-observations at the Seychelles and at Arusha, Tanganyika Territory, in October 1941. Observations at Kabete, Nairobi, were discontinued during February to September but were resumed in October 1941. Dr. Walter reports that every effort was made during the report-year to obtain monthly observations at Kabete to check secular variation. During 1942 he expected also to reoccupy stations at Fort Hall, Nanyuki, Naivasha, Gilgil, Equator, and Nakura in Kenya.

At Hermanus Observatory, where the secular variation of the Earth's field is very large, Dr. A. Ogg, of the Magnetic Branch of the Trigonometical Survey of the Union of South Africa, obtained measurements at frequent intervals using CIW magnetometer-inductor 17. Through Dr. Ogg were received also the annual values for the observatory at Elisabethville and recent charts of magnetic declination with estimates of secular change for the Belgian Congo.

*Australia.* The personnel of the Aerial, Geological and Geophysical Survey of Northern Australia of the Australian Department of Mines has been banded together for the duration of the war at the Commonwealth's Department of Supply and Development at Canberra. The survey originally planned using CIW magnetometer-inductor 18 was completed. According to a report on August 12, 1942 from Chief Geologist J. M. Rayner, the original project for the continuation of the isogonic map of Australia, "based almost entirely on the observations made by the Department of Terrestrial Magnetism," was greatly extended during the course of the reductions, and isogonic maps going far to the north and east of Australia were prepared. These included isoporic charts for recent epochs.

The latest corrections in standards for CIW magnetometer 6 and dip-circle 226, on loan for survey-operations to the Adelaide Observatory of South Australia, were compiled and forwarded to Astronomer G. F. Dodwell,

who is compiling the results of observations made with them by his staff.

*New Zealand.* The Department cooperates with the New Zealand Magnetic Survey of the New Zealand Department of Scientific and Industrial Research through the loan of CIW magnetometer-inductor 27. Director H. F. Baird reports that by March 1942, despite the extension of the war, well distributed CIW repeat and new stations totaled 55, and that 7 more would be completed in March. These results are especially needed for the investigation of secular changes and the preparation of isoporic charts for the past decade.

Dr. E. Marsden, Secretary of the New Zealand Department of Scientific and Industrial Research, used a newly developed CIW instrument to make magnetic measurements in the Pacific Ocean and New Zealand.

*North, Central, and South America.* CIW magnetometer-inductors 26 and 28 were loaned to the United States Coast and Geodetic Survey for use in the Western Hemisphere on surveys (1) in the western United States and (2) in the Caribbean area and Central and South America, through arrangements made by the United States Department of State.

During the latter trip of 25,000 miles—95 per cent by air—56 stations, most of which were reoccupations of CIW stations, were occupied, as follows: Balboa and Coco Solo in the Canal Zone; Pinar del Río, Havana, Camaguay, and Santiago in Cuba; Kingston (Stony Hill), Woods, and Old Harbor in Jamaica; Port-au-Prince in Haiti; Puerto Plata and Ciudad Trujillo in the Dominican Republic; San Juan (Observatory) in Puerto Rico; St. Johns, Umbrella, Rat, and Henzell in Antigua; Port-of-Spain, Gordon, Harts Cut, and Junction in Trinidad; Georgetown, Bartica, and British Guiana 114 in British Guiana; Vassouras (Observatory), Rio de Janeiro, Bahia, and Belem in Brazil; Montevideo in Uruguay; Barcelona, Caracas, Ciudad Bolívar, Barquisimeto, Valera, and Maracaibo in Venezuela; Barranquilla, Cartagena, Medellín, Pleyades, Puerto Colombia, and

Bogotá in Colombia; San José and Uvita Island in Costa Rica; Teoloyucan, Ciudad del Carmen, and Chetumal in Mexico; Colon, Old Panama, and David in Panama; Corinto and Managuas in Nicaragua; Puerto Cortez and Tegucigalpa in Honduras; La Union and San Salvador in El Salvador; Guatemala City in Guatemala. Eight magnetic stations were subsequently occupied in Bermuda, following which the complete standardization of instrumental equipment was completed at the Cheltenham Magnetic Observatory.

*Arctic.* The Louise A. Boyd Arctic Expedition of 1941 (June to November), under the leadership of Miss Boyd on Captain Bartlett's schooner *Effie M. Morrissey*, obtained magnetic data using CIW magnetometer-inductor 16 and dip-circle 222. Instructions and compilations of data were prepared by the Department, and the observers were instructed in methods of observation and computation for magnetic and astronomical determinations. Control of in-

strumental constants and corrections on standards were effected at the Cheltenham Magnetic Observatory. The stations occupied, italics indicating repeat-stations, were: *St. John's* in Newfoundland; *Dundas Harbor* in North Devon Island; *Pond's Inlet*, Clyde River, Cape Searle, *Pangnirtung*, and York Sound (south side of Frobisher Bay) on Baffin Island; and *Hopedale* and *Battle Harbor* in Labrador. The expedition was under the scientific sponsorship of the National Bureau of Standards. Ionospheric characteristics as determined by special radio measurements, auroral conditions, and measurements of ultraviolet-light intensities were also included in the program. The magnetic results are valuable in a region where data are especially needed.

Miss Boyd supplied values of magnetic declination obtained on her East Greenland Expedition of 1938 at 4 stations on Jan Mayen Island, 1 in Spitzbergen, and 7 in eastern Greenland.

### OBSERVATORY-WORK

Johnston was in charge of the Section of Observatory-Work. The reductions of magnetic data and computations in connection with the analysis of the magnetic results from the observatories were continued with the assistance of Scott and Miss Balsam. McNish and Torreson were engaged in war investigations throughout the report-year. McNish prepared a paper on "The aurora and geomagnetic storm of September 18-19, 1941." Wait discussed further the atmospheric-electric and meteorological data from Watheroo and Huancayo for the 11-year period 1924-1934; he and Torreson published a paper on these investigations. Wait continued to study the atmospheric-electric data for Watheroo and Huancayo and completed two additional papers, one on the effect of smoke on the Watheroo data, and the other on simultaneous atmospheric-electric observations over the oceans and at Watheroo.

The complete geomagnetic program was maintained at Watheroo and Huancayo observatories. At Watheroo, in cooperation with the Australian Commonwealth Department of Air, weekly summaries of ionospheric data, forecasts of conditions likely to affect short-wave radio transmission, and predicted values of maximum usable frequencies for various distances were prepared. The geomagnetic program at both observatories comprises continuous records of the three magnetic elements ( $D$ ,  $H$ , and  $Z$ ), positive and negative conductivity of the air, atmospheric potential-gradient at the surface, earth-currents in two directions at right angles with duplicate lines, heights of the ionosphere by fixed frequency and automatic multifrequency, daily spectrohelioscopic observations during the periods assigned by the International Astronomical Union, and the meteorological elements. A three-compo-

nent seismograph and precision cosmic-ray meter are also operated at Huancayo.

The Section continued the reduction of the magnetic data from Watheroo and Huancayo observatories. Final reductions were made for the year 1940 and preliminary compilations for the year 1941. The final values of the magnetic elements for all days during 1940 and the preliminary values for 1941 are shown in table 4.

The extensive program of reporting weekly the magnetic three-hour-range in-

duced indices  $K_r$ . The world-wide  $K_w$  is introduced in order to obtain an average of the reduced indices, in which  $K_r$  from high-latitude stations are given double and equatorial stations single weights. Individual indices from each of the seven American-operated observatories and the weighted mean index ( $K_w$ ) are mailed out weekly by the Section to governmental agencies and other interested persons.  $K$ -indices and other cosmic data were published quarterly. In order to characterize

TABLE 4

ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT THE WATHEROO AND HUANCAYO MAGNETIC OBSERVATORIES AS BASED ON MAGNETOGRAMS FOR ALL DAYS, 1940 AND 1941

YEAR	DECLINATION, <i>D</i>	INCLINATION, <i>I</i>	INTENSITY-COMPONENTS					LOCAL MAGNETIC CONSTANT, <i>G</i>
			Horizontal, <i>H</i> ( $\gamma$ )	Total, <i>F</i> ( $\gamma$ )	North-south, <i>X</i> ( $\gamma$ )	East-west, <i>Y</i> ( $\gamma$ )	Vertical, <i>Z</i> ( $\gamma$ )	
WATHEROO MAGNETIC OBSERVATORY								
1940.....	3° 15'8 W	64° 24'3 S	24700	57175	24660	—1406	—51564	35704
1941.....	3 12.2 W	64 25.1 S	24705	57216	24666	—1381	—51607	35723
HUANCAYO MAGNETIC OBSERVATORY								
1940.....	6 55.9 E	2 14.3 N	29517	29540	29302	3562	1154	29524
1941.....	6 50.3 E	2 13.6 N	29471	29493	29262	3509	1146	29477

dex  $K$  between 0 and 9 (Year Book No. 40, p. 99) was continued, in conformity with the resolution passed by the Association of Terrestrial Magnetism and Electricity of the International Union of Geodesy and Geophysics, at its Seventh Assembly in September 1939.  $K$ -indices for the 7-day period ending Greenwich midnight on Friday are regularly transmitted to the Washington office both by our observatories and by the five magnetic observatories of the United States Coast and Geodetic Survey. The  $K$ -indices are assembled by the Section and standardized by means of keys for transforming  $K$  into

each day's succession of eight three-hour intervals by a single index with due allowance for the *actual* ranges experienced, the computation of daily indices  $B$  was continued and completed for the year 1941. Despite disordered world-affairs, correspondence with foreign observatories in regard to  $K$ -indices and character-figures (on scale 0, 1, and 2) was maintained.  $K$ -indices have been supplied by 12 observatories, namely (in order of geomagnetic latitude), Lerwick, Dombås, Meanook, Eskdalemuir, Rude Skov, Agincourt, Witteveen, Abinger, Niemegek, San Fernando, Zô-Sè, and Cape Town (Hermanus). The

*K*-indices for the second half of 1940 and first half of 1941 for these 12 magnetic observatories were tabulated. Those for the second half of 1940, together with summaries for the whole of 1940, were published. *K*-indices for the year 1940 for Sodankylä, Slutzk, Chambon-la-Forêt, Apia, Kuyper, Pilar, and Amberley were tabulated and are awaiting publication, as are also compilations of daily mean *K*-indices from 25 observatories (7 American-operated and 18 world-wide) for January to December 1940.

The Department and the United States Coast and Geodetic Survey, in cooperation with the communication-services of the United States Army and the United States Navy and several amateur radio stations, continued to supply the American half-day and whole-day magnetic character-figures ( $C_A$ ) based upon the reports of the seven American-operated observatories. Whole-day magnetic character-figures ( $C$ ) were assembled for those world-wide magnetic observatories reporting them.

Cooperation in the magnetic and atmospheric-electric programs of the Department was given by various magnetic observatories. Our international magnetic standards were maintained at Cheltenham Magnetic Observatory, and the continuous recordings of atmospheric conductivity (positive and negative) and potential-gradient and of earth-currents were continued at the Tucson Magnetic Observatory; both of these observatories are operated by the United States Coast and Geodetic Survey.

The Section continued the reduction of the geomagnetic data from the Watheroo and Huancayo observatories. Final reductions were made for the year 1940 and preliminary compilations for the year 1941.

Compilations to make current the annual values of all the geomagnetic elements ( $D$ ,  $H$ ,  $Z$ ,  $I$ ,  $X$ ,  $Y$ , and  $F$ ) for the world's

magnetic observatories were begun by Ennis and completed by Scott after the former's death.

#### OPERATIONS AT OBSERVATORIES

*Watheroo Magnetic Observatory, Watheroo, Western Australia.* The Watheroo Magnetic Observatory is situated in latitude  $30^{\circ} 19.1$  south and longitude  $115^{\circ} 52.6$  east of Greenwich, 244 meters (800 feet) above sea-level.

The Eschenhagen magnetograph was in continuous operation. Weekly determinations of the values of the base-lines for the three elements were made in the absolute observatory. Control of the scale-value of the horizontal-intensity variometer was maintained by monthly determinations, using the method of magnetic deflections. Scale-values of the vertical-intensity variometer were determined daily by the electrical method.

The la Cour rapid-running magnetograph was in operation throughout the year. Determinations of scale-value were made at monthly intervals, using the electrical method. The monthly scale-values for both the Eschenhagen and la Cour magnetographs are shown in table 5.

The preliminary values for the annual changes in the magnetic elements during 1940.5 to 1941.5 are: declination,  $+3.6$ ; horizontal intensity,  $+5$  gammas; vertical intensity,  $-43$  gammas; inclination,  $-0.8$  (see table 4).

Numerous requests have been received for magnetic data, principally the values of declination at various points in the state of Western Australia, from the different branches of the defense services, and in order to supply this information in a suitable form, an isogonic map of Western Australia was prepared showing lines of equal magnetic declination for the year 1942; copies of this map have been furnished to the military authorities and to the Department of Lands and Surveys.

As in previous years, three-hour-range indices,  $K$ , were assigned from an examination



of the Eschenhagen traces and transmitted weekly to Washington through the Australian Commonwealth Department of Air.

There were 12 major magnetic disturbances during 1941; table 6 shows details of these storms, full descriptions of which were forwarded to Washington monthly.

The recording of earth-currents was continued; the system of electrodes and methods of registration will be found described in previous reports. The scalings and prepara-

made on days when meteorological conditions were favorable.

Positive and negative air-conductivities were also recorded continuously. From the tabulated hourly values of both potential-gradient and conductivity, certain days had to be excluded owing to adverse weather conditions or the smoke from bush-fires. Preliminary mean values of the atmospheric-electric elements are shown in table 7.

The automatic multifrequency ionospheric recording apparatus has functioned practically

TABLE 5

SCALE-VALUES OF MAGNETOGRAPHS, WATHEROO  
MAGNETIC OBSERVATORY, 1941

MONTH	SCALE-VALUES IN $\gamma$ /MM			
	ESCHENHAGEN		LA COUR	
	<i>H</i> (reduced to base- line)	<i>Z</i> (means of daily values)	<i>H</i>	<i>Z</i>
January...	2.38	3.34	4.61	2.98
February...	2.39	3.35	4.51	2.70
March...	2.38	3.36	4.44	2.82
April.....	2.39	3.33	4.47	2.97
May.....	2.40	3.35	4.47	3.26
June.....	2.39	3.21	4.42	3.20
July.....	2.39	3.23	4.44	3.26
August....	2.40	3.27	4.59	3.57
September	2.40	3.29	4.42	3.51
October...	2.43	3.30	4.56	3.24
November	2.40	3.34	4.51	3.06
December..	2.40	3.25	4.48	3.06

tion of monthly curves of diurnal variation were kept current; by this means electrode-faults or anomalies can be quickly detected. The earth-current recorder, being visual, has proved valuable in the early detection of the commencement of magnetic disturbances and gives a warning of disturbed conditions in the ionosphere.

Air-potentials were continuously recorded as in previous years. The reduction of the recorded values to the potential which would be recorded at a point 1 meter above a plane surface was controlled by series of eye-observations, using the stretched-wire method,

continuously throughout the year, the only interruptions being due to necessary maintenance, control-observations, adjustments, and minor repairs. The antenna-systems were serviced as required. Scalings and reductions have been maintained strictly current. Tables 8 and 9 show the mean hourly values of ionospheric data for 1941. The Australian Commonwealth Department of Air was supplied with weekly coded reports of ionospheric conditions and also, when necessary, warning of approaching conditions likely to affect high-frequency radio transmission. Predicted values of maximum usable frequency

TABLE 6

DETAILS OF MAGNETIC DISTURBANCES RECORDED AT  
THE WATHEROO MAGNETIC OBSERVATORY  
DURING 1941

DATE	RANGES		
	<i>H</i> ( $\gamma$ )	<i>D</i> ( $^{\circ}$ )	<i>Z</i> ( $\gamma$ )
January 3-4.....	85	14	59
January 24.....	107	24	135
March 1-2.....	658	77	>350
March 13-14.....	149	21	162
March 28-31.....	185	32	>194
April 24-25.....	148	22	144
July 4-7*.....	563	65	>215
August 4-5.....	168	26	195
September 18-19*....	684	73	>336
October 31-November 1	173	19	149
November 27-28.....	148	18	129
December 1-2.....	147	29	202

\* Aurora australis observed.

over various distances of path were regularly supplied to the Department of Air. Ionospheric data were communicated to the Radio Research Board of the Commonwealth Council for Scientific and Industrial Research, the Chief Radio Inspector of the Postmaster-General's Department, and the (United States) National Bureau of Standards.

A regular watch was kept, using the Hale spectrohelioscope, for solar activity, and re-

Scalings and reductions were maintained practically current until the end of 1941, when, owing to the great reduction in the staff, some of the scalings had to be postponed. Essential control-observations and reductions, however, were kept current.

W. C. Parkinson continued as Observer-in-Charge. McCarthy left on July 15, 1941, to go with the Radio Research Board; he was replaced by Norman (beginning July 1,

TABLE 7

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,  
WATHEROO MAGNETIC OBSERVATORY, 1941

MONTH	POTENTIAL-GRADIENT			AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU				
	No. selected days	Reduction-factor	Value (v/m)	No. selected days	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+ / \lambda_-)$
January.....	19	....	92.8	17	1.84	1.72	3.56	1.07
February.....	19	....	95.7	19	1.42	1.31	2.73	1.08
March.....	24	1.18	94.9	23	1.38	1.25	2.63	1.10
April.....	18	....	66.8	16	1.86	1.69	3.55	1.10
May.....	20	....	57.4	19	2.49	2.33	4.82	1.07
June.....	14	....	65.0	10	2.52	2.26	4.78	1.12
July.....	15	....	63.6	11	2.43	2.11	4.54	1.15
August.....	21	1.05	71.2	26	2.25	1.87	4.12	1.20
September.....	21	....	76.4	26	1.94	1.57	3.51	1.24
October.....	25	....	70.2	26	1.75	1.70	3.45	1.03
November.....	20	....	84.0	22	1.55	1.40	2.95	1.11
December.....	12	....	79.1	24	1.63	1.58	3.21	1.03
Totals and means.....	228	1.12	77.3	239	1.92	1.73	3.65	1.11

ports of the observations were transmitted monthly to Washington.

Observations of meteorological phenomena were made regularly as in previous years. Monthly summaries were supplied, as before, to the Commonwealth Weather Bureau, and, in addition, on and after January 9, 1942, telegraphic coded weather-reports were prepared and transmitted at 09<sup>h</sup>, 12<sup>h</sup>, and 18<sup>h</sup> daily (120° east meridian time) to the Divisional Forecasting Offices of the Department of Air at Perth and Geraldton. Table 10 shows rainfall at Watheroo during 1941.

1941). Muhling resigned on August 31, 1941, to enlist in the Australian Navy; Lucas left on January 29, 1942, to take up work at the University of Western Australia. On January 1, 1942, W. D. Parkinson was appointed as temporary part-time observer, the remainder of his time being occupied with work at the Observatory for the Department of Air. A mechanic and assistant mechanic are regularly employed. The general hand who left in January 1942 could not be replaced because it was impossible to obtain an able-bodied man for the work.

TABLE 8

PRELIMINARY MEAN HOURLY VALUES OF IONOSPHERIC DATA,  
WATHEROO MAGNETIC OBSERVATORY, 1941

120° east meridian time (h)	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	$f_E^o$ (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	$f_{min}$ (Mc/sec)
00.....	...	...	335	260	....	....	4.36	....
01.....	...	...	332	256	....	....	4.24	....
02.....	...	...	327	251	....	....	4.06	....
03.....	...	...	322	249	....	....	3.90	....
04.....	...	...	319	250	....	....	3.70	....
05.....	...	...	315	252	....	....	3.54	....
06.....	...	...	298	247	1.70	....	3.89	0.60
07.....	244	233	280	256	2.11	3.90	5.11	0.68
08.....	230	225	284	274	2.67	4.04	6.07	0.79
09.....	225	217	298	293	3.00	4.30	6.65	0.83
10.....	223	215	305	296	3.21	4.54	7.20	0.90
11.....	218	210	309	298	3.30	4.63	7.57	0.92
12.....	217	211	309	300	3.34	4.69	7.82	0.95
13.....	221	214	314	298	3.31	4.67	7.92	0.94
14.....	227	219	308	292	3.25	4.56	8.02	0.91
15.....	230	222	303	284	3.08	4.36	7.91	0.88
16.....	232	226	294	271	2.80	4.11	7.57	0.79
17.....	240	231	289	254	2.28	3.97	7.17	0.73
18.....	...	...	287	234	1.74	....	6.44	0.65
19.....	...	...	300	230	....	....	5.56	....
20.....	...	...	313	237	....	....	5.03	....
21.....	...	...	328	250	....	....	4.65	....
22.....	...	...	339	259	....	....	4.51	....
23.....	...	...	342	262	....	....	4.44	....

TABLE 9

PRELIMINARY MONTHLY MEANS OF HOURLY VALUES OF IONOSPHERIC DATA,  
WATHEROO MAGNETIC OBSERVATORY, 1941

Month	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	$f_F^o$ (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	$f_{min}$ (Mc/sec)
January.....	233	226	343	300	2.83	4.44	6.19	0.76
February.....	233	226	336	289	2.95	4.29	5.65	0.77
March.....	230	219	316	266	2.75	4.33	6.07	0.75
April.....	227	220	295	250	2.57	4.28	5.84	0.73
May.....	225	216	283	239	2.56	3.98	5.16	0.70
June.....	224	215	280	236	2.55	3.85	5.00	0.72
July.....	230	219	285	244	2.63	3.98	4.78	0.83
August.....	224	218	294	248	2.69	4.30	5.16	0.87
September....	223	226	305	256	2.76	4.42	5.75	0.99
October.....	229	220	319	267	2.88	4.39	6.25	0.87
November....	239	230	332	287	2.87	4.36	6.30	0.94
December....	231	225	338	298	2.97	4.44	6.49	0.84
Means.....	229	222	310	265	2.75	4.26	5.72	0.81

Acknowledgment is gratefully made to various government departments for assistance, especially valuable under present conditions; particularly to the Department of Trade and Customs for their continued favorable action with regard to equipment and supplies entering the country, and also to the Wireless Branch of the Postmaster General's Department. The Signals Branch of the Department of Air has also been most helpful in transmitting magnetic messages weekly.

TABLE 10  
RAINFALL AT WATHEROO MAGNETIC  
OBSERVATORY DURING 1941

Month	Monthly total (in.)	No. days	Average for 24 years (in.)
January.....	0.00	0	0.34
February.....	0.88	2	0.56
March.....	0.05	3	1.04
April.....	1.83	12	0.92
May.....	2.36	8	2.17
June.....	3.76	16	3.39
July.....	1.89	17	2.95
August.....	1.43	11	2.21
September....	1.65	13	1.27
October.....	0.78	6	0.85
November....	0.66	6	0.33
December....	0.13	3	0.37
Totals.....	15.42	97	16.40

To the present reduced Observatory staff, who have labored under considerable disadvantages during the past report-year, great credit is due for the comparatively satisfactory condition of the work on June 30, 1942.

*Huancayo Magnetic Observatory.* The Huancayo Magnetic Observatory is situated about  $8\frac{1}{2}$  miles about west of the town of Huancayo in the central valley of the Peruvian Cordillera. It is in latitude  $12^{\circ} 02' 7''$  south and longitude  $75^{\circ} 20' 4''$  west and at an altitude of 3350 meters (11,000 feet) above sea-level.

Practically all the Observatory's work is done by the use of automatically recording apparatus, most of which record photographi-

cally. Time-control marks on the records are made electrically by lights or mechanical devices operated by a master clock and program-machine which are frequently checked and adjusted through the use of radio time-signals. Except for the ionospheric recorder and the meteorological recorders, all instruments record intervals of Greenwich days, since traces are changed daily at  $19^h, 75^{\circ}$  west meridian time. Daily development of all photographic traces permits excellent control of instrumental equipment.

The magnetographs consist of two separate three-variometer units: an Eschenhagen and a rapid-run la Cour, both of which operated continuously during the year. A low-sensitivity la Cour *H*-variometer also recorded on the Eschenhagen magnetogram. Weekly absolute observations were made with magnetometer and earth-inductor for the control of base-lines. Scale-value determinations for the *H*- and *Z*-variometers of the la Cour magnetograph were made on or near the 15th of each month by the Helmholtz-coil method. Helmholtz-coil scale-value determinations were also made for the Eschenhagen magnetograph, once each week for the *H*- and *D*-variometers and three times a week for the *Z*-variometer.

Air-potentials were recorded continuously with the standard potential-gradient apparatus. Scale-values were determined once every two weeks and reduction-factors quarterly by comparisons with potentials measured on the standardization-plot near by. Positive and negative conductivities of the air were recorded continuously and scale-value determinations made every two weeks.

Earth-current potentials were recorded continuously on the Leeds and Northrup recording potentiometer for two separate systems of north-south and east-west pairs of electrodes.

The multifrequency ionospheric equipment operated with only minor breaks in continuity for maintenance and repair, except during a period in the latter part of February and the early days of March when two or more days of record were lost on three occasions because of instrumental difficulties. The fixed-fre-

quency equipment recorded regularly until the time of the difficulty in February, but was disconnected at that time and was only returned to operation in the latter part of June. Daily control-observations and checks were kept up consistently through the year and monthly calibrations were made. Compilations of the scaled values from the traces were completed within a few days of the month's end and the tabulations forwarded to Washington by air.

The program of daily morning meteorological observations was continued as in previous years, with recording instruments operating continuously in the meteorological shelter and in the atmospheric-electric and cosmic-ray buildings. Daily determinations were made of condensation-nuclei at a point near the meteorological shelter each morning at the time of the meteorological readings. The minimum temperature during the year was  $-4^{\circ}.3$  C and the maximum was  $24^{\circ}.6$  C; the lowest monthly mean minimum was  $0^{\circ}.43$  C in July 1941 and the highest monthly mean maximum was  $21^{\circ}.93$  in November of the same year. The rainfall from July 1, 1941 to June 30, 1942 totaled 32.36 inches, well above the average for previous years. As before, tabulations of meteorological data were supplied monthly to the Instituto Nacional de Meteorología e Hidrología (formerly Servicio Meteorológico Nacional del Perú), to the Centro Geográfica Departamental de Junín, and on several occasions to other governmental agencies and to private persons interested in the climate of the Sierra.

Cosmic-ray meter model C no. 2 recorded continuously with only minor losses of trace. The weekly checks of high-potential balance and of the electrometer zeros were continued.

During the month of June 1941, Ledig was able to be of assistance to the cosmic-ray expedition of Dr. Arthur H. Compton and his associates Drs. Wollan, Hughes, and Hilberry. Help was given them in connection with the diplomatic procedure of obtaining free entry for their scientific equipment of 95 cases. The personnel were acclimated to the high altitude of the Andes by visits at the

Observatory before leaving for Mahr Tunnel and San Cristobal mine (in Peru), where Wilson cloud-chamber observations were made at an altitude of over 15,000 feet. On June 25, Ledig went by plane to Arequipa and thence to Mollendo by automobile with Dr. Hilberry. He assisted until June 30 (when he returned by plane to Huancayo) in passing the equipment through the customs and in unpacking and assembling it, preparatory to Dr. Hilberry's ascent of El Misti (19,000 feet). Ledig's son Paul accompanied Dr. Hilberry as interpreter and general assistant on the ascent of El Misti, where records were obtained with a Wilson cloud-chamber.

Two Wenner horizontal-component seismometers and a Benioff vertical-component seismometer recorded satisfactorily through the year. Analyses were made of all important seismic disturbances and forwarded with the monthly journals, and 23 of these were sufficiently important to be sent in the international seismic code with the weekly broadcast of magnetic data.

Daily observations of the Sun with the Hale spectrohelioscope were made as weather-conditions permitted, at the assigned observational periods. Though only six times during the year were there seen activities on the Sun that merited careful description, monthly reports were prepared and transmitted to Washington.

Although the weekly broadcast of scientific data was ordered discontinued in January 1942 by the Departamento General de Radiotelegrafía del Perú, consideration of the Observatory's case permitted a reinauguration of this service in March.

The preliminary values for the annual changes in the magnetic elements during 1940.5 and 1941.5 are: declination,  $-5^{\circ}.6$ ; horizontal intensity,  $-46$  gammas; vertical intensity,  $-8$  gammas; inclination,  $-0^{\circ}.7$  (see table 4).

Preliminary monthly mean values of the atmospheric-electric results for the year 1941 are given in table 11, and the mean hourly values of ionospheric data and their monthly means for 1941 are listed in tables 12 and 13.

As always, the Observatory has enjoyed the confidence and friendship of the local Peruvian population, and there has been evidence of an increased interest among all Peruvians in learning something of the work. There were occasional visitors from the American colony in Peru as well as British and American travelers in the country. Assistance by the United States Embassy to Peru in obtaining free entry for equipment and supplies is gratefully acknowledged, and sincere

tion of all members of the staff made possible the successful continuance of the extended geophysical program.

*College Observatory, Alaska.* In pursuance of a comprehensive geophysical program, the Department maintained in cooperation with the University of Alaska at College, Alaska, a complete magnetic, auroral, and ionospheric observatory. This Observatory is in the zone of maximum auroral activity, about 5 miles west of Fairbanks, in latitude  $64^{\circ} 51.4$  north,

TABLE 11

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,  
HUANCAYO MAGNETIC OBSERVATORY, 1941

MONTH	NO. SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU			
		Reduction- factor	Value (v/m)	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+ / \lambda_-)$
January.....	3	....	65.1	3.30	3.01	6.31	1.10
February.....	3	....	87.2	2.63	2.20	4.83	1.20
March.....	3	....	53.1	3.43	3.57	7.00	0.96
April.....	5	....	39.9	4.19	4.77	8.96	0.88
May.....	8	....	48.3	3.91	4.29	8.20	0.91
June.....	9	....	48.0	4.60	4.79	9.39	0.96
July.....	16	1.17	52.2	3.89	4.45	8.34	0.87
August.....	12	....	48.8	4.38	4.81	9.19	0.91
September.....	10	....	49.6	4.05	4.04	8.09	1.00
October.....	6	1.14	41.9	4.65	4.87	9.52	0.94
November.....	5	....	47.6	4.34	4.89	9.23	0.89
December.....	3	....	54.0	3.19	3.28	6.47	0.97
Totals and means...	83	1.16	53.0	3.88	4.08	7.96	0.97

appreciation is expressed for the support and cooperation of persons in positions of authority in the Peruvian government.

P. G. Ledig as Observer-in-Charge and M. W. Jones as observer were members of the scientific staff throughout the year. R. C. Coile resigned February 9, 1942 to join the American Army. He was replaced by A. A. Giesecke, Jr., on January 29. E. J. Chernosky arrived early in May to become the fourth member of the scientific staff. The clerical assistants, T. Astete, A. Macha, and V. Murga, continued to give excellent service in the reduction of data and general operation of the Observatory. The enthusiastic coopera-

longitude  $147^{\circ} 49.3$  west, at an altitude of about 1250 feet (381 meters).

The insensitive la Cour magnetograph with accessory instruments for base-line and scale-value determinations was mounted on concrete piers housed in buildings occupied by the Second International Polar Year Expedition (October 1932 to March 1933) at the same location.

The magnetograph was in continuous operation from August 1, 1941. The scale-values of the variometers were 18.2 $\gamma$  per millimeter for horizontal intensity, 27.4 $\gamma$  per millimeter for vertical intensity, and 5.18 per millimeter for declination. Preliminary mean values of

TABLE 12

PRELIMINARY MEAN HOURLY VALUES OF IONOSPHERIC DATA,  
HUANCAYO MAGNETIC OBSERVATORY, 1941

75° west meridian time (h)	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	$f_E^o$ (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	$f_{min}$ (Mc/sec)
00.....	...	...	318	260	....	....	6.79	....
01.....	...	...	313	260	....	....	6.08	....
02.....	...	...	312	263	....	....	5.36	....
03.....	...	...	310	268	....	....	4.70	....
04.....	...	...	311	273	....	....	4.13	....
05.....	...	...	316	278	0.78	....	3.74	0.64
06.....	...	...	317	269	1.59	....	5.13	0.72
07.....	261	245	322	262	2.44	4.35	7.65	0.87
08.....	250	231	368	304	2.92	4.67	8.99	1.08
09.....	237	225	419	328	3.36	4.81	9.40	1.30
10.....	227	220	448	352	3.63	4.88	9.23	1.46
11.....	221	217	454	369	3.80	4.90	8.93	1.62
12.....	219	214	457	374	3.85	4.90	8.78	1.66
13.....	218	213	457	373	3.77	4.86	8.86	1.61
14.....	223	213	452	362	3.60	4.81	9.10	1.51
15.....	236	216	444	343	3.25	4.71	9.33	1.29
16.....	260	226	442	316	2.80	4.54	9.47	1.12
17.....	...	...	429	262	2.28	....	9.49	0.90
18.....	...	...	420	281	1.30	....	9.34	0.73
19.....	...	...	441	314	0.84	....	8.75	0.66
20.....	...	...	422	316	....	....	8.28	....
21.....	...	...	385	295	....	....	8.06	....
22.....	...	...	357	279	....	....	7.73	....
23.....	...	...	333	266	....	....	7.26	....

TABLE 13

PRELIMINARY MONTHLY MEANS OF HOURLY VALUES OF IONOSPHERIC DATA,  
HUANCAYO MAGNETIC OBSERVATORY, 1941

Month	$h_{F_1}^{max}$ (km)	$h_{F_1}^{min}$ (km)	$h_{F_2}^{max}$ (km)	$h_{F_2}^{min}$ (km)	$f_E^o$ (Mc/sec)	$f_{F_1}^o$ (Mc/sec)	$f_{F_2}^o$ (Mc/sec)	$f_{min}$ (Mc/sec)
January.....	237	218	401	315	2.90	5.02	8.00	1.28
February.....	228	220	387	292	2.89	4.89	8.77	1.20
March.....	241	228	388	294	2.80	4.81	8.51	1.26
April.....	248	233	384	293	2.63	4.74	7.94	1.08
May.....	250	233	380	305	2.44	4.62	6.65	1.00
June.....	226	216	356	292	2.39	4.59	6.14	0.97
July.....	227	214	365	307	2.49	4.63	6.11	1.07
August.....	229	217	378	297	2.60	4.77	7.08	1.05
September....	233	220	389	303	2.67	4.73	7.81	1.28
October.....	236	222	388	302	2.74	4.66	8.49	1.29
November....	235	222	401	314	2.75	4.72	8.52	1.19
December....	233	219	405	320	2.81	4.75	8.26	1.06
Means.....	235	222	385	303	2.68	4.74	7.69	1.14

the magnetic elements, considering all days from July 26, 1941 to June 30, 1942, are: declination,  $29^{\circ} 52.9$  east; horizontal intensity, 12576 $\gamma$ ; vertical intensity, 55347 $\gamma$ ; inclination,  $77^{\circ} 11.9$  north. The resulting preliminary rates for the annual changes, utilizing average values of the magnetic elements for epoch 1933.5 as supplied by the United States Coast and Geodetic Survey, are: declination, 3.8 west; horizontal intensity, 0 $\gamma$ ; vertical intensity, -22 $\gamma$ ; inclination, -0.3.

The ionospheric installation—similar to that at the Watheroo and Huancayo observatories—was completed in June 1941. Field-intensity recorders were installed early in July. Since then complete exploration of the ionosphere through automatic continuous photographic recording has been made. The data comprise direct measurements, or deductions from such measurements, of a group of sixteen quantities descriptive of the time-space distribution of ionospheric ionization vertically above the station. The considerable quantity of homogeneous data resulting from the year's operation will require several years for complete analysis, but several important contributions have already been made on the basis of preliminary work. The theoretical postulations of Appleton and Builder (*Proc. Phys. Soc.*, vol. 45, pp. 208-220, 1933) concerning longitudinal type propagation of electromagnetic waves through the ionosphere in the presence of the Earth's magnetic field were confirmed empirically. Ionospheric trends and variations obtained at College were found to be in reasonably good agreement with those expected from extrapolation of observations at stations in the temperate zones. Comparison of theoretical with experimental values of maximum usable frequency added evidence in support of Newbern Smith's method (*Proc. Inst. Radio Eng.*, vol. 27, pp. 332-347, 1939) of deduction, when corrected for ionospheric curvature. A technique was developed for applying these methods to large quantities of data in order that mean values may be converted directly.

Other geophysical investigations at College included both visual and photographic auroral observations during hours of darkness from

October 1941 through April 1942. Estimates of auroral indices based on brilliance, activity, and extent of the displays, as well as details regarding their form and location, were obtained from visual observations at half-hour intervals. The photographic program was confined for the most part to photographs of the region around the zenith obtained at 2.5-minute intervals on 16-mm film by an automatic camera developed at the Department, and built around a Paillard-Bolex moving-picture camera. Preliminary analysis of the visual records indicates a pronounced daily variation in auroral activity with a maximum centering around 02<sup>h</sup> 00<sup>m</sup> local time. Studies of the occurrence of auroras with concomitant magnetic and ionospheric phenomena show that both magnetic activity and abnormal sporadic *E*-region ionization are closely correlated with auroral activity. The correlation was particularly evident when auroras in the zenith alone were considered.

Berkner was in charge of the Observatory through July 1941, when he transferred the Observatory to Bramhall as Physicist-in-Charge and returned to Washington to enter active duty in the Navy as Lieutenant-Commander, September 1, 1941. The other members of the staff were Chief Assistant Seaton, Observer E. Wolff, Assistant Observers Ohlsen (to September 19, 1941, and from January 15, 1942), St. Amand (to May 16, 1942), and Caulk (to September 15, 1941), and Guards Atkinson and Heinrich for part time. The successful prosecution of the extensive program and the prompt compilations of data and reports reflect the competence and energy of the staff.

#### COOPERATION WITH OTHER OBSERVATORIES

*Cheltenham Magnetic Observatory, United States.* The cooperative program with the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey was continued. CIW instruments on loan to the Observatory were used to control standards in the horizontal and vertical components of geomagnetic intensity. Continuous cosmic-



ray records were made with the CIW model C precision meter. Necessary observations for standardization and control of constants for CIW instruments before and after assignments to the field were made. The interest and help of the Washington staff of the Division of Geomagnetism and Seismology of the Survey and of Observer-in-Charge A. K. Ludy and assistants at the Observatory made for marked efficiency in the cooperative work.

*Apia Observatory, Western Samoa.* The Department continued cooperation with the Apia Observatory, through its Acting Director, H. B. Sapsford, and staff, in geomagnetic and atmospheric-electric programs. This Observatory also undertakes observations in other fields of geophysics, including meteorology and seismology.

CIW magnetometer 9 and CIW Schulze earth-inductor 2 were used for absolute observations of declination, horizontal intensity, and inclination. Eschenhagen variometers and a Godhavn balance were used to obtain continuous photographic records of declination, horizontal intensity, and vertical intensity. The scale-value of the Godhavn balance proved satisfactorily constant during the report-year. The scale-value as determined with a Helmholtz coil was 1.317 per millimeter and by the oscillation method outlined by la Cour 1.337 per millimeter.

*K*-indices were determined for the year 1940. *K*-indices were scaled for the month of January 1938, using 300 gammas (0.003 CGS unit) for the lower limit of the range for a *K*-index of 9. The frequency-distribution of the various *K*-indices when compared with that at Cheltenham and Honolulu was satisfactory. Seasonal variation curves in  $S_q$  for international quiet days during the summer and winter solstices and the equinoxes were prepared for sunspot-maximum. The amount of the diurnal variation due to lunar effect was determined, and its range was of the order of 3 to 6 gammas.

Atmospheric potential-gradient was measured with a Benndorf electrometer. The leak-free potentiometric method of Gish and Sherman was used to determine the reduction-factor of the Land Station, and results

showed that its value was still 1.00. During 1941, 146 days of zero-character were recorded, with a mean value of 127 volts per meter. The monthly number of zero-days and average potential-gradients are shown in table 14. The annual average hourly values in volts per meter based on the monthly means are as follows: 95, 95, 94, 98, 100, 109, 151, 223, 229, 169, 133, 120, 110, 103, 102, 101, 101, 101, 120, 167, 170, 136, 112, and 100.

The Land Station was closed on December 31, 1941, and the series of atmospheric potential-gradient measurements conducted in cooperation with the Department since 1921 was thus brought to an end. At the close of the first World War the New Zealand government assumed the operation of the Observatory but was unable to provide for the expense of the atmospheric-electric observations. In order to maintain the continuity of the work, the Department entered into a cooperative agreement first with the New Zealand Department of External Affairs and later with the New Zealand Department of Scientific and Industrial Research, to which the financial and technical control of the Observatory was transferred in 1929.

*Tucson Magnetic Observatory, United States.* Complete and continuous registrations of atmospheric potential-gradient, of positive and negative air-conductivities, and of earth-currents were made at the Tucson Magnetic Observatory of the United States Coast and Geodetic Survey. Observer-in-Charge J. H. Nelson and assistants continued most efficiently this program made possible by the cooperation of the Coast and Geodetic Survey, the Bell Telephone Laboratories, and the Department. Table 15 summarizes the monthly and annual values of the atmospheric-electric elements, as computed by Mrs. G. Dewey, part-time assistant of the Department at Tucson. At Washington, Sherman continued the preparation of the data for publication.

*Hermanus Magnetic Observatory, South Africa.* CIW magnetometer 17 with earth-inductor attachment continued in use at the Hermanus Magnetic Observatory. The Department cooperates here with the Trigonometrical

TABLE 14

POTENTIAL-GRADIENT AND METEOROLOGICAL SUMMARY, APIA OBSERVATORY, 1941

MONTH	POTENTIAL-GRADIENT		METEOROLOGICAL ELEMENTS					
	No. zero-days	Value (v/m)	Pressure (mb)	Temp. (°F)	Rainfall (in.)	Rel. hum. 9 A.M. (per cent)	Sunshine (hrs.)	Wind velocity (miles/hr.)
January.....	10	120*	1008.3	81	6.76	77	228.2	4.8
February.....	4	136	1005.4	82	20.20	82	154.3	7.2
March.....	6	128	1008.7	81	12.56	78	246.3	6.7
April.....	11	118	1009.9	82	4.43	79	241.3	7.8
May.....	15	116	1010.9	81	1.62	78	218.1	7.2
June.....	18	132†	1011.4	80	2.29	77	240.0	6.8
July.....	13	129	1012.1	78	6.07	76	211.3	9.7
August.....	18	122	1011.1	79	6.95	79	247.9	8.6
September.....	11	123	1011.4	79	2.35	77	234.8	10.6
October.....	18	118	1010.2	79	4.25	71	248.7	7.8
November.....	16	146	1008.7	80	6.93	75	248.0	10.4
December.....	6	134	1008.4	81	6.07	79	232.2	7.1
Totals and means.....	146	127	1009.7	80.2	80.48	77	2751.1	7.9

\* Based on mean of 9 zero days.

† Based on mean of 16 zero days.

TABLE 15

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS,  
TUCSON MAGNETIC OBSERVATORY, 1941

MONTH	NO. SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU				
		Reduction-factor	Value (v/m)	All complete days	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+ / \lambda_-)$
January.....	17	....	72.2	31	2.01	1.77	3.78	1.14
February.....	18	....	66.3	26	2.03	1.89	3.92	1.07
March.....	18	1.33	58.0	31	2.00	1.82	3.82	1.10
April.....	23	....	48.5	28	2.19	2.09	4.28	1.05
May.....	22	....	48.2	31	2.29	2.22	4.51	1.03
June.....	26	1.28	51.2	28	2.58	2.46	5.04	1.05
July.....	16	....	52.6	28	2.22	2.01	4.23	1.10
August.....	16	....	55.6	29	2.21	2.00	4.21	1.10
September.....	20	....	53.6	24	2.70	2.45	5.15	1.10
October.....	25	1.22	49.7	26	2.70	2.46	5.16	1.10
November.....	26	....	57.6	30	2.27	2.10	4.37	1.08
December.....	24	....	71.0	26	2.00	1.80	3.80	1.11
Totals and means..	251	1.28	57.0	338	2.27	2.09	4.36	1.09

Survey of the Union of South Africa, of which Dr. A. Ogg is Magnetic Adviser. Contact was maintained through Dr. Ogg with the Elizabethville Observatory in Belgian Congo.

*Godhavn Observatory, Greenland.* Because of the war, cooperation was extended to the Godhavn Observatory by providing maintenance supplies and instrumental replacements, in addition to carrying on the cosmic-ray program already under way there through collaboration with the Cosmic-Ray Committee of the Institution. Thus it has been possible to continue the whole valuable geophysical program at this important station, which otherwise would have been interrupted by the impossibility of receiving supplies from Denmark.

*Christchurch Observatory, New Zealand.* The collaboration in cosmic-ray recordings and compilations at the Amberley station of the Christchurch Observatory in New Zealand was maintained. Supplies were furnished as necessary.

*Royal Alfred Observatory, Mauritius.* The loan of CIW marine-inductor 4 was continued for the control of the vertical-intensity records.

*Teoloyucan Observatory, Mexico.* Dr. J. Gallo, Director of the National Observatory of Mexico in Teoloyucan, continued the cosmic-ray recordings there. Necessary supplies for maintenance of the program were prepared and forwarded.

*United States Antarctic Expedition (1940-1941).* Physicist Roy G. Fitzsimmons, of the United States Department of the Interior, completed, as guest-investigator at the Department of Terrestrial Magnetism from July 1941 through June 1942, the compilations and discussion of the magnetic data obtained at the Little America Observatory and in the field during the United States Antarctic Expedition of 1940-1941. The manuscript is now in the hands of the Department of the Interior for publication. The final average magnetic elements at Little America III, West Base (not identical with the observatory-locations of the Byrd Expeditions of 1929-1930 and 1934-1935) were for the epoch 1940.7 (April 1940 to January 1941): declination,

$104^{\circ} 57.5'$  east; horizontal intensity, 0.10050 CGS unit; inclination,  $81^{\circ} 20'$  south (these values supersede preliminary values given in Year Book No. 40, p. 109). Unfortunately there appears to be some local disturbance in the region about Little America, at least in declination. The mean epochs and values obtained by the two earlier expeditions are: Little America I, declination (1930.0)  $106^{\circ} 49.4'$  east, horizontal intensity (1929.7) 0.09042 CGS unit, inclination (1929.7)  $82^{\circ} 17.9'$  south; Little America II, declination (1934.6)  $106^{\circ} 33.2'$  east, horizontal intensity (1934.6) 0.09444 CGS unit, inclination (1934.6)  $81^{\circ} 53.6'$  south. The resulting rates of annual changes, reckoning east declination, horizontal intensity, and north inclination as positive, are: declination, 1930.0 to 1934.6,  $-3.5'$ , and 1934.6 to 1940.7,  $-15.7'$  (?); horizontal intensity, 1929.7 to 1934.6, +90 gammas, and 1934.6 to 1940.7, +99 gammas; inclination, 1929.7 to 1934.6,  $+5.0'$ , and 1934.6 to 1940.7,  $+5.5'$ .

Assistant Physicist Murray A. Wiener, of the United States Department of the Interior, also of the Expedition, as guest-investigator at the Department of Terrestrial Magnetism from July 3 to December 9, 1941 completed the compilation and discussion of the auroral observations made in 1940 (see Year Book No. 40, p. 110). The manuscript is now also awaiting publication by the Department of the Interior.

The cosmic-ray data obtained from cosmic-ray meters loaned by the Department of Terrestrial Magnetism were compiled and discussed by Korff (see Year Book No. 41, pp. 97-98).

The autumn general meeting of the American Philosophical Society (November 21 and 22, 1941), at Philadelphia, heard reports on the scientific results of the Expedition in a symposium on the "Interest of the United States in Polar Lands." The program of eleven papers included one by Fitzsimmons giving a preliminary report on the magnetic and seismic program, and one by Korff giving a report on the cosmic-ray results.

## PUBLICATIONS ON THE "CARNEGIE" DATA

The series of volumes under the general title "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929, under command of Captain J. P. Ault" is now in course of publication. Three quarto volumes on biology will be distributed in July and September 1942. These are: "Biology—I: The copepods of the plankton gathered during the last cruise of the *Carnegie*" (237 pages), by Charles B. Wilson; "Biology—II: The oceanic Tintinnina of the plankton gathered during the last cruise of the *Carnegie*" (163 pages), by Arthur Shackleton Campbell; and (by offset printing) "Biology—III: Studies in the morphology, taxonomy, and ecology of the Peridiniales" (129 pages), by Herbert W. Graham.

The next manuscripts in the series, master-copy now in preparation for direct offset printing, are: "Meteorology—I: Meteorological results of the last cruise of the *Carnegie*," by Woodrow C. Jacobs and Katherine B. Clarke-Hafstad; "Meteorology—II: Upper wind observations and results obtained on the last cruise of the *Carnegie*," by Andrew Thomson; "Physical

Oceanography—I: Results within physical oceanography of the last cruise of the *Carnegie*," by Harald U. Sverdrup; and "Physical Oceanography—II: Marine bottom samples collected in the Pacific Ocean on the last cruise of the *Carnegie*," by Roger Randall Revelle.

The decision to use the offset method of printing for the volumes other than Biology I and Biology II will make for economy of publication. This method will also permit earlier issue of the remaining memoirs of the series, publication of which, because of the other urgent demands on the limited personnel of the Department, has had unfortunately to be so long delayed. This delay has been mitigated to some extent by the fact that the original manuscripts for the various reports, and extracts therefrom, have been made available from time to time for use and consultation by other investigators engaged in oceanographic research. Digests and summaries of the memoirs have also been published, as indicated in the bibliographies of publications listed in previous annual reports of the Department.

## INSTRUMENT-SHOP

The work of the Instrument-Shop during the report-year totaled approximately 30,800 man-hours, of which 9300 were devoted to the construction of the cyclotron. Approximately 15,300 man-hours were for war purposes, and 6200 for construction of new equipment and experimental apparatus, repairs and improvements to instruments and apparatus, buildings and grounds, and miscellaneous items. The total included some 2600 hours overtime. Steiner continued in charge, with the skilled assistance of Lorz, Haase, Ksanda, Fogel, A. Smith (retired), Balsam, Huff (to July 11, 1941), P. A. Johnson, Buy-

nitzky, Caherty, Thomas (from July 28, 1941), Niemeyer, Roes (to July 31, 1941), Schloer (from April 1, 1942), A. M. Schmidt (to December 31, 1941), F. R. Nichols (to September 10, 1941, and from June 15, 1942), and Garves (February 25 to May 31, 1942). Building Superintendent Smallwood also assisted in the shop and looked after the burden, increased greatly by war operations, of maintenance of buildings and site, with the effective assistance of Malvin and Quade.

The main items of design and construction were: three Gish-Hess ionization-chambers and one electrometer-housing at-

tachment for use with these chambers; automatic auroral camera for use at College, Alaska; 24 new cams for the ionospheric apparatus at College Observatory; two automatic voltage-controllers, one each for the Huancayo and Watheroo observatories; and some improvements in the self-justifying typewriter. Under maintenance may be mentioned numerous replacement-parts for ionospheric apparatus

at observatories, overhauling of two la Cour recorder-clocks for the Godhavn Observatory, and repairs and adjustments to magnetometer-inductors 26 and 28 and earth-inductors 48 and 171.

Because of the heavy demands made by war work, a one-story addition to the shop with 1800 square feet of floor space was completed.

### MISCELLANEOUS ACTIVITIES

Some lectures, addresses, and contributions to meetings and physics colloquia, not already mentioned or listed in the bibliography accompanying this report, may be noted as follows: Eleventh Arthur Lecture, Smithsonian Institution, February 26, 1942, "The Sun and the Earth's magnetic field," by Fleming. American Geophysical Union at its annual meeting, April 4, 1942: "Researches in terrestrial magnetism and electricity at the Department of Terrestrial Magnetism, Carnegie Institution of Washington, for year April 1941 to March 1942," by Fleming; "Abrupt daily changes in condensation-nuclei," by Jones and Ledig; "Geomagnetic bays, their frequencies and current-systems," by H. B. Silsbee and E. H. Vestine; "Atmospheric-electric results from simultaneous observations over the ocean and at Watheroo, Western Australia," by Wait. American Institute of Electrical Engineers, University of Maryland Branch, December 10, 1941, "Scientific activities at the Huancayo Magnetic Observatory of the Department of Terrestrial Magnetism, Carnegie Institution of Washington," by Wells. Engineers Club of Baltimore, Maryland, November 26, 1941, "Tagged atoms," by Cowie. National Capital Amateur Astronomers Association, March 7, 1942, "Magnetic effects of the Sun," by McNish. Navy Yard Colloquium, Washington, April 1, 1942, "Fluctuations

in the Earth's magnetism," by Vestine. Physics Colloquium of Washington: December 10, 1941, "Astronomical theory of the ice-caps," and April 1, 1942, "The rotation of the stars," by Gamow. Philosophical Society of Washington, December 6, 1941, "Great geomagnetic storms of the present sunspot-cycle," by McNish. Radio broadcast at College, Alaska (KFAR), December 30, 1941, "Northern lights," by Bramhall, Rainey, and Seaton. McNish prepared for publication in "The progress of science" an article on "Geomagnetism and geoelectricity."

Members of staff took part in scientific meetings and organizations as officers and members and on special committees. Naturally the present emergency curtails such activities, but they are therefore the more important in that maintenance of scientific life, progress, and instruction is also of great importance to the war effort. So far as conditions have permitted, contacts were kept with geophysicists of the United Nations to insure preservation of the framework of those organizations, such as the International Union of Geodesy and Geophysics, which must be depended upon for international scientific cooperation on the return of peace. Members of our staff have served the American Geophysical Union—the organization representing international relations for the United States through the

National Research Council—in various capacities.

*Library.* The falling off in the receipt of publications from Europe reported last year was further accentuated by the extension of the war to countries which had not been directly engaged in hostilities prior to December 1941. Despite this, accessions totaled 456, as compared with 442 for the last report-year, bringing the total number of accessioned books and pamphlets to 26,659. As in former years, all articles in current periodicals bearing on subjects under investigation by the Department were catalogued.

Librarian Harradon continued as co-editor of the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, dealing especially with the foreign contributions, preparation of notes, reviews of books and reports, and annotated lists of recent publications on geomagnetism, geoelectricity, and allied subjects. His list of published papers by members of the Department to December 31, 1941 showed a total of 2162. Reprints of these papers were regularly distributed to interested institutions and individuals. During the latter part of the report-year, Harradon spent some time in study of the early works on terrestrial magnetism reproduced by G. Hellmann in his *Rara magnetica*, with a view to the possible publication of translations or modernized versions of some of these documents as a contribution to the history of geomagnetism.

Dove continued as Secretary to the Director and had charge of the general files of the Department and the storage and distribution of reprints. He typed a large number of reports and manuscripts, and prepared for binding the "Contributions" from the Department for 1941.

Harradon continued as Secretary of the Section of Meteorology of the American Geophysical Union and as Chairman of the

Committee on Statutes and By-Laws of the Union. A biographical sketch of the late Dr. Louis A. Bauer, first Director of the Department of Terrestrial Magnetism, was prepared for the *Dictionary of American biography*.

As in the past, the facilities of the library were made available to research workers and students from educational institutions and government bureaus. More than in any previous year, the library has been used by specialists, particularly by those engaged on problems concerned with the war. Information on geomagnetism and allied subjects was freely furnished in response to a large number of letters emanating from diverse sources. The practice of interlibrary loans was continued, and reciprocal and cordial relations were maintained with other libraries, particularly with the Library of Congress.

*Office administration.* The war work undertaken for the government under contracts with the Office of Scientific Research and Development and the Navy Department has required most of the regular time and a great deal of overtime in correspondence, placing of orders, accounting, and matters concerned with the activities of over 200 added temporary employees. Air-raid instructions were prepared by M. B. Smith, Steiner, Smallwood, and Scott. Much time was required in connection with war-work procedures, contracts, requests for priorities, and transfers of personnel. The procedures for maintaining the usual departmental activities, both in Washington and at the three observatories, were complicated also by the emergency conditions and required much more time than ordinarily is the case.

The many details involved in the practically fivefold expansion of administration and personnel were most efficiently handled by M. B. Smith, administrative as-

sistant, and the members of the regular and temporary clerical staff.

Capello, secretary and property-clerk, had charge of shipments and inventory, maintained detailed monthly statements of time and costs of work in the shop, and prepared manuscripts. The drawings, charts, and illustrations for publications

and reports were prepared by Hendrix. He and J. W. Green also handled the photographic work. The records received from the observatories and field were arranged and filed by Miss Balsam, who with Capello kept current the cataloguing of photographic films and index-albums of prints.

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## SPECIAL PROJECTS: TERRESTRIAL SCIENCES

COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS. *Progress report for the period July 1941 to June 1942.* (For previous reports <sup>1</sup> see Year Books Nos. 32-40.)

With the entry of the United States into World War II, activities in cosmic-ray research have been necessarily reduced because of (a) diversion of personnel to war-research problems, (b) impossibility of continuing relations with workers and observatories other than those of the United Nations, and (c) curtailment of laboratory facilities and of equipment and transportation for field-work. Good progress was nevertheless made during the year ended June 30, 1942, as is evidenced by the appended reports of investigators with whom the Committee has been privileged to cooperate through the support of the Carnegie Institution of Washington and the Carnegie Corporation.

There is not the slightest doubt among physicists that the generous and continued support accorded the program of cosmic-ray research during the past decade has added greatly to knowledge and has encouraged "in the broadest and most liberal manner investigation, research, and discovery." The field of cosmic-ray research presents appeal and fascination similar to those found in the outstanding astronomical studies carried on at the Mount Wilson Observatory and so generously supported without undue emphasis upon possible "practical" applications. The cosmic-ray program has forwarded discoveries of the positron, of the mesotron, and of pair-production as a form of energy-production into matter, and information on electrodynamics of the interaction of high-energy electrons, gamma rays, mesotrons, protons,

and alpha particles with atomic nuclei. But the further support of the program should be based on what is not known about cosmic rays rather than on what is known about them. Among outstanding questions in this field are: (1) the source of cosmic radiation; (2) the nature of the primary radiation; (3) the method of production of mesotrons; (4) the nature of the mesotron; and (5) the interaction of matter with extremely high-energy particles.

In a memorandum on "The purposes of cosmic-ray investigation," prepared in January 1942 at the request of the President of the Carnegie Corporation, Dr. S. A. Korff comments on certain aspects of this field. Extracts from that memorandum follow:

"The origin of cosmic rays is at the present time a mystery. It is evidently tied up with the larger aspects of the universe, and it will almost certainly be some time before we understand it fully. On the other hand this in itself provides an intriguing spur to the initiative of investigators. Since the cosmic rays are so abundant and so powerful and since they appear to come from all directions in space regardless of whether or not these regions are occupied by matter, it seems quite possible that the cosmic rays will eventually help to throw some light on the now completely unanswerable questions such as how long has the universe been here, how long may it be expected to continue, how is it supplied with energy, and how much of this energy is left.

"In the realm of high-energy physics cosmic rays provide the only means for research at energies greater than those produced by cyclotrons. The present 225-ton cyclotrons generate energies in the neighborhood of 30 million

<sup>1</sup> For statement on formation, purposes, and policies of the Committee see Year Book No. 38 (1938-1939), pp. 335-349.

electron-volts. The one under construction in California is expected to produce one hundred million electron-volts and possibly more—an energy which should be just enough to generate mesotrons in the laboratory. Until this large cyclotron is completed, cosmic rays will provide the only means for studying these particles; even after it is completed the cosmic rays will provide the only means for studying any but the very slowest mesotrons. The cyclotron now under construction represents doubtless the practical limit which will not be exceeded for many years to come. The whole energy-range beyond this limit is accessible only through cosmic rays.

“Cyclotrons have been of the utmost importance in developing a new field of physics. They were able to produce radiation with the same energy as that with which the nuclei of atoms are held together. In other words, energies produced by the cyclotron and nuclear-binding energies are comparable. The particles accelerated by cyclotrons can penetrate therefore into nuclei and produce transmutations and other nuclear changes. A variety of new elements, many of them of the utmost value in medicine and others usable as tracers in complex biological, chemical, and physiological reactions have been thus produced. The next big field to be explored in physics is that in which the bombarding energies are much greater than the binding energies of the nuclei. The only tool of research in this field is cosmic-ray investigation. Large factors are available in the energies which may be observed . . . . These energies are sufficient to disrupt atoms completely, and to permit study of the forces and laws which are at work in their interiors . . . . At the present time we can produce million-volt x-rays, and use them for medical treatments. To know what the effect of a billion-volt x-ray will be, we must turn to cosmic rays, which can and do produce such rays and have already revealed some of the properties possessed by them. In this field cosmic rays . . . promise to reveal much about the structure of matter.

“In the possibly ‘practical’ realm, cosmic rays are already beginning to be an important

adjunct in meteorology. Since the cosmic rays come from outer space and are absorbed in the atmosphere through which they pass the intensity at sea-level depends on the amount of air above the instrument, and hence on the atmospheric pressure. The cosmic-ray mesotrons also experience a type of absorption due to ‘decay,’ since they are unstable and spontaneously disintegrate. This decay depends on time and hence on the length of the path over which they pass. Hence the cosmic-ray intensity depends not only on the amount of the atmosphere but also on its distribution, since if the air is warmer, the total atmosphere will expand and the mesotrons which are almost all produced near the top of the atmosphere will decay more because of having to travel further. Consequently a study of cosmic rays gives the meteorologist a picture of what may be happening at altitudes even higher than those accessible to sounding balloons.

“. . . It is well known that disturbances on the sun’s surface produce magnetic storms and concomitant radio fade-outs and dislocations in wire telegraphy and telephony . . . . These same storms also affect the intensity of the cosmic rays, especially since the cosmic rays depend on the earth’s magnetic field. The cosmic rays will provide therefore an additional technique for studying the earth’s magnetic field and the changes in it which result from magnetic storms . . . .”

Statements of progress from investigators and organizations with whom the Committee has cooperated actively are appended to this report. The study on motion of cosmic-ray particles in the geomagnetic field by Professor M. S. Vallarta at Massachusetts Institute of Technology remains at a virtual standstill because of delay in completion of the differential analyzer and of limitations imposed by the war. The following paragraphs briefly summarize results and progress during the year ended June 30, 1942.

*Investigations.* Despite the demands of the emergency and consequent depletion

of personnel, Professor A. H. Compton succeeded in maintaining an effective group for the studies of cosmic rays at the University of Chicago. Of special interest were the results of the mountain experiments showing the production of mesotrons by photons and protons, and of the study of the production of mesotrons near the top of the atmosphere by incoming protons. Apparently there was demonstrated for the first time, in the production of mesotrons by photons traversing matter, the interaction of electrical and nuclear forces.

S. E. Forbush, on leave of absence during the entire year on a war-research assignment, found time for general supervision, at the Department of Terrestrial Magnetism, of the compilations and details of maintenance of the cosmic-ray meters at the Cheltenham, Huancayo, Teoloyucan, Christchurch, and Godhavn observatories. Communication with Greenland became more difficult, but, through the courtesy of the Consul-General of Denmark at New York, the American-Danish Greenland Commission, and the United States Coast Guard, the necessary supplies, batteries, and replacements for operation and maintenance were forwarded from the Department of Terrestrial Magnetism.

Miss Isabelle Lange continued the reduction and analysis of the photographic records from observatories despite the necessity of giving a considerable part of her time to computations concerned with war research. The cosmic-ray variations associated with the magnetic storm of March 1, 1942 afford a good example of the need of continued photographic registrations at widely separated stations.

Professor Victor F. Hess and associates at Fordham University corroborated the view that the so-called temperature-effect

of cosmic rays is primarily an effect of atmospheric mass-distribution variations.

At the Bartol Research Foundation, Dr. Thomas H. Johnson, R. P. Shutt, and Sergio de Benedetti made progress on construction of the large high-pressure Wilson cloud-chamber. They completed the analysis of investigations of the composition of the cosmic radiation in the lower atmosphere, and of the processes of interaction of cosmic rays with matter.

Professor S. A. Korff, now at New York University, from analysis of the cosmic-ray data obtained on the United States Antarctic Service Expedition during 1940, found that the fluctuations in cosmic-ray intensity correlated somewhat better with changes in the temperature of the upper atmosphere than with those at sea-level. From experiments at Swarthmore, in Denver, and on the summit of Mount Evans, it was found that a large percentage of neutrons were associated with cosmic-ray showers.

Dr. Robert A. Millikan and his associates and students at the California Institute of Technology made tests at various stations in Mexico and in the United States as to the origin of cosmic-ray energies, and obtained results apparently confirming the hypothesis proposed in the report of last year. The 60-cm high-resolution cloud-chamber for study of the properties of mesotrons was completed. Improvements of cosmic-ray Geiger counters and studies of their mechanisms were made.

Wilson M. Powell and C. E. Nielsen, at the University of California, studied the mass of the mesotron and prepared special equipment for tests to be made at Mount Evans during July and August 1942.

The Committee kept contacts by correspondence and personal conference with many investigators. Grateful acknowledgment is made to the directors and staff-

members of the organizations which continued their contributions and services to the program; these include the Danish Meteorological Institute, the National Astronomical Observatory of Mexico, the New Zealand Department of Scientific and Industrial Research, and the United States Coast and Geodetic Survey.

W. S. ADAMS

J. A. FLEMING, *Chairman*

F. E. WRIGHT

### COSMIC-RAY MAGNET

ROBERT B. BRODE

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The pressure of war research has prevented further work on the study of mesotrons with the magnet of the Carnegie Institution at the University of California. The magnet has been, however, in nearly continuous use since December 1941 as an essential instrument in a war-research problem. The design of the magnet was fortunately such that it could be used without alteration for this purpose.

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### REPORT ON COSMIC-RAY RESEARCH AT THE UNIVERSITY OF CHICAGO

A. H. COMPTON

*University of Chicago, Chicago, Illinois*

*Mountain experiments.* During the year 1941-1942 high-altitude experiments on mountains have been performed at stations in Peru and Colorado.

The work by E. O. Wollan and Donald Hughes at the San Cristobal Mine (4750 meters) near Lima, and of Norman Hilberry and Ann Hepburn Hilberry on El Misti (5840 meters) near Arequipa, was

mentioned in last year's report. The persons engaged on these studies were assigned to other urgent work before more than a preliminary analysis of their results could be prepared. This analysis was, however, sufficient to establish the presence of both protons and mesotrons of intermediate energy at these altitudes, and to confirm the very high energy (up to  $10^{18}$  electron-volts) of the primary particles responsible for the "giant showers" that become prominent at the higher altitudes.

On Mount Evans, in 1941, David B. Hall and Marcel Schein studied the energy distribution of mesotrons. Using four counter-telescopes, it was possible to obtain the energy-spectrum of mesotrons with good precision. Using a tray of Geiger-Müller counters, a method was developed for distinguishing between slow mesotrons and electrons. This arrangement made it possible to obtain the spectrum of low-energy mesotrons by pure absorption methods. The spectrum shows, at the elevation of 4340 meters, a pronounced maximum at an energy of about  $3 \times 10^8$  electron-volts, whereas at sea-level the corresponding maximum occurs at an energy of about  $10^9$  electron-volts. Such a change in the spectrum of the mesotron had been qualitatively observed in the airplane experiments of Schein, Wollan, and Groetzinger at altitudes of 7500 meters. Theoretical calculations indicate that at least a large part of the slow mesotrons observed at Mount Evans must have been produced at altitudes very close to the place where the apparatus was located.

Victor H. Regener constructed a counter-outfit to study the production of mesotrons. His apparatus consisted of about 150 counter-tubes arranged in trays. Different thicknesses of lead (up to 35 cm) were interposed between the counter-trays. Each individual counter-tube was connected to

a neon-flasher indicating the passage of an ionizing particle through the counter. Working first at Mount Evans, Regener obtained about 100,000 pictures, each showing at least one cosmic-ray particle traversing the counter-set. Several hundred of these pictures show definite evidence of production of mesotrons in the material interposed between the counters.

At altitudes of 4000 meters, 90 per cent of the mesotrons are produced by non-ionizing rays and 10 per cent by ionizing particles. Two kinds of production-process were found: (a) There exists a production of single mesotrons with energies of about  $10^8$  electron-volts by non-ionizing rays which seem to be photons. No process has previously been observed in which a direct interaction occurs between the electromagnetic and the nuclear field of force. Undoubtedly the nuclear production of a slow mesotron by a photon would represent such a process. A further study of this phenomenon is in preparation. (b) Three per cent of the pictures obtained on Mount Evans show a multiple production of mesotrons. These mesotrons originate mostly from a penetrating neutral radiation. The number of counter-tubes simultaneously discharged indicates an average multiplicity of 6 to 8 mesotrons per producing particle. The mesotrons produced are capable of penetrating a lead thickness of about 20 cm, which corresponds to an average mesotron energy of  $3 \times 10^8$  electron-volts. This process seems similar in nature to the multiple production of mesotrons by protons found by Schein, Jesse, and Wollan (1941) close to the top of the atmosphere.

Marcel Schein and David B. Hall measured the zenith-angle distribution of mesotrons and electrons. It was found that the slow mesotrons have a different zenith-angle distribution from that of electrons and fast mesotrons. Schein and Hall con-

clude that the soft component does not originate from electrons entering the earth's atmosphere, but from the decay of high-energy mesotrons.

The east-west asymmetry of mesotrons was studied by Schein and Hall on Mount Evans. An excess of 2 per cent from the west was observed. T. H. Johnson has tried to explain the high-altitude asymmetry by a bending of the paths of mesotrons by the earth's magnetic field. The excess of positives present in the spectrum of mesotrons leads to a slight directional asymmetry. The magnitude of the effect found on Mount Evans indicates an average path of these mesotrons between 20 and 30 km. This means that they must have been produced close to the top of the atmosphere.

Variations in the vertical intensity of mesotrons and electrons were compared with barometric changes by Schein and Hall on Mount Evans. For high-energy mesotrons the barometer-effect was found to be of the order 5 per cent per cm of mercury. For slow mesotrons with an energy of  $10^8$  electron-volts the barometer-effect was as large as 25 per cent. The low-energy mesotrons are also strongly influenced by magnetic disturbances, a phenomenon which was noticed on Mount Evans during the magnetic storm on September 18, 1941.

W. H. Bostick, using a cloud-chamber in the field of a permanent magnet, analyzed the nature of low-energy particles emerging below 2 cm of lead. In addition to the usual shower pictures, a relatively large number of simple mesotron-tracks were obtained. Many of them show definite curvature in a field of 1200 gauss, which means that their energy is below  $5 \times 10^8$  electron-volts. The relative number of these mesotrons is in accordance with the energy-spectrum of mesotrons found on Mount Evans.

Working at Climax, Colorado, in December, V. H. Regener and R. Lapp studied the production of mesotrons in different materials (paraffin, aluminum, iron, and lead). These experiments show that in light materials the number of mesotrons produced by non-ionizing radiation is much higher than had been expected. In all the materials several mesotrons are produced simultaneously with an average multiplicity of 6 to 8. The cross-section of the production-process was found to be equal to the area of the nucleus hit by the primary particle. The mesotron production-process found in the stratosphere has also a cross-section of nuclear dimensions. It thus seems well established that the production of mesotrons is a nuclear process.

P. Pompeia and E. O. Wollan constructed a counter-outfit to measure the lifetime of the mesotron by a time-delay experiment. The apparatus was similar to that used by Rasetti in Canada. After extensive tests on the ground, the apparatus was set up by Pompeia and Lapp at Echo Lake (Colorado) and later on top of Mount Evans. The experiments are not yet completely analyzed. The preliminary results, however, indicate that several mesotrons were stopped in the absorber without giving out a decay-electron in the time-interval of 1 to 15 microseconds after they were stopped. It would be premature to conclude that the mesotron is directly captured by the nucleus, or that the average lifetime of the mesotron within the solid absorber is much shorter than as measured by Rossi and his collaborators, until further tests are made.

*Time-variations of cosmic rays.* By courtesy of the Department of Terrestrial Magnetism of the Carnegie Institution, the model-C recording cosmic-ray meters at Christchurch (New Zealand), Huancayo (Peru), Teoloyucan (Mexico), Cheltenham (Maryland, United States), and God-

havn (Greenland) have been kept in operation. Other work has prevented full attention to their analysis. It is hoped, however, that the program of observation, intended to operate through a sunspot-cycle, may be completed.

N. F. Beardsley has assembled a counter-apparatus of large sensitive area for studies of time-variations in cosmic-ray intensity on the ground. This apparatus is now in operation and data are being continuously collected.

Victor H. Regener is constructing five identical counter-outfits which it is planned to station permanently at five different places in the United States. Each of these outfits can be used to measure the changes in vertical intensity of mesotrons with atmospheric pressure and temperature.

*Composition of cosmic rays.* Marcel Schein and M. Jona have sent counter-outfits carried by balloons into the stratosphere to study the neutral component of cosmic radiation. It was found that within an experimental error of about 2 per cent there is no multiple production of mesotrons by neutral rays present close to the top of the atmosphere. This means that in the stratosphere the number of high-energy neutrons, if any, must be very small. The apparatus used was also capable of registering large showers generated in lead by a high-energy neutral radiation. The absence of these showers strongly indicates that there cannot be any appreciable amount of high-energy  $\gamma$ -radiation entering the earth's atmosphere from the outside. These results confirm the absence of high-energy neutral rays entering the atmosphere.

E. Dershem and M. Schein developed a new type of balloon counter-outfit which can be used for cosmic-ray studies in the stratosphere. In this outfit the coincidence-counts of four different counter-telescopes are collected independently by an elec-

trometer-system. The position of the fiber of the electrometer is recorded on a rotating film. This apparatus, which is capable of registering high-speed counting rates, was sent up once to the stratosphere for measuring the intensity of the soft component. Further flights to high altitudes are in preparation.

*Production of secondary radiation.* The experiments of Schein, Jesse, and Wollan on the production of mesotrons in the stratosphere have been continued by M. Schein and M. Jona. Multiple production of mesotrons by non-ionizing rays could not be found. It therefore seems that the majority of the mesotrons in the stratosphere are produced by ionizing rays (protons). The angular spread of the mesotrons produced in the stratosphere was investigated and found to be much smaller than on Mount Evans as measured by Regener. This can be explained by the fact that close to the top of the atmosphere the primaries which produce the mesotrons have considerably higher energies (about  $10^{10}$  electron-volts) than the average energy of the mesotron-producing radiation on Mount Evans, which is around  $2 \times 10^9$  electron-volts.

In a further study, the number of mesotrons stopped between 4 and 8 cm of lead has been measured as a function of altitude. These mesotrons have an energy of about  $10^8$  electron-volts. The intensity-curve obtained shows the presence of these slow mesotrons in altitudes below 25 km. The curve has a pronounced maximum at a pressure of about 5 cm of mercury. To determine the exact position of this maximum, further high-altitude flights must be made. The presence of slow mesotrons in altitudes below 25 km can be explained on the basis of the assumption made by Carlson and Schein that the mesotrons are produced with an average energy of about

$5 \times 10^8$  electron-volts and then slowed down by ionization-loss in the air. There is thus no reason to assume, as has sometimes been suggested, that mesotrons occur with a life many times less than that of those now known.

M. Shapiro studied the nature of the particles in cosmic-ray "stars" found in photographic emulsions. His analysis leads to the conclusion that 90 per cent of the tracks in "stars" are protons. The rest is probably due to alpha particles.

*Properties of mesotrons.* L. Seren measured the number of knock-on electrons in equilibrium with mesotrons. The measurements were carried out in a counter-controlled cloud-chamber. Seren found that the number of collision-electrons originating from mesotrons is in good agreement with theoretical predictions. This is a significant verification of the laws of electrodynamics as applied to particles with extremely high energies.

*Personnel.* The following members of the Physics Department of the University of Chicago were engaged on this work in July 1941: William P. Jesse, Marcel Schein, Ernest O. Wollan, Donald J. Hughes, Ardis T. Monk, Elmer Dershem, Niel F. Beardsley, and Victor H. Regener. As guests of the laboratory, Paulus Pompeia, Norman Hilberry, and Ann Hepburn Hilberry were active. As graduate students, Winston H. Bostick, Leo Seren, and David B. Hall have made notable contributions. The urgency of other work has required during the year the withdrawal of William P. Jesse, Ernest O. Wollan, Donald J. Hughes, and Ardis T. Monk, as well as of the guests and graduate students just mentioned. The addition of Pierre Auger and A. Rogozinski has greatly helped our situation. The opportunities for important achievement in this field have never seemed more promising.



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## STATISTICAL INVESTIGATIONS OF COSMIC-RAY VARIATIONS

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*Instruments.* Operation of the Carnegie Institution's precision cosmic-ray meters was continued at the following stations: Cheltenham (Maryland, United States) Magnetic Observatory of the United States Coast and Geodetic Survey, meter C-1, A. K. Ludy and John Hershberger in charge; Huancayo (Peru) Magnetic Observatory of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, meter C-2, P. G. Ledig in charge; National Astronomical Observatory of

Mexico at Teoloyucan (D. F., Mexico), meter C-4, Dr. Joaquin Gallo in charge; Amberley Branch of the Christchurch (New Zealand) Magnetic Observatory of the Department of Scientific and Industrial Research, meter C-5, J. W. Beagley in charge; Godhavn (Greenland) Magnetic Observatory of the Danish Meteorological Institute, meter C-6, K. Thiesen and H. P. Barfod in charge.

*Reduction of data.* Scalings and tabulations of hourly values of cosmic-ray ionization, bursts, and barometric pressure were continued for the records from Cheltenham, Huancayo, and Godhavn, and at Christchurch (by J. W. Beagley). Owing to pressure of war work it has not been possible to maintain the complete reductions current.

*Investigations.* A further striking example of the magnetic-storm effect on cosmic-ray intensity occurred during the magnetic storm of March 1, 1942. In the 6-hour interval beginning with the sudden commencement of this magnetic storm, the cosmic-ray intensity decreased about 8 per cent simultaneously at Huancayo and at Cheltenham. Sufficient data on magnetic-storm effects on cosmic-ray intensity should soon be available for statistical investigations which may assist in understanding the mechanism involved.

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## REPORT ON COSMIC-RAY WORK

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*Studies on latitude- and temperature-effect of cosmic rays aboard the "Santa Ana," between New York and Valparaiso.*

The registrations of cosmic-ray intensities with a model-C cosmic-ray meter, begun in September 1940, were continued until February 1942. Later registrations were not evaluated since the ship's route was changed and the logs were not available on account of the war. Twelve round trips had been completed in February 1942; the data on the first three trips were incomplete, and therefore only the observations during trips 4 to 12 are being used for publication. A preliminary report was given by Rev. Edward B. Berry, S. J., at the meeting of the American Physical Society in December 1941. (A complete report will be published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, September 1942.)

From the correlation of cosmic-ray intensities, corrected for barometric readings, with temperature at sea-level, the temperature-coefficients for all geomagnetic latitudes on the route from New York to Chile were computed. The smallest values of these temperature-coefficients were found to be grouped symmetrically around the geographic equator. The latitude-effect curve, corrected for effect of temperature, was obtained and is generally in agreement with curves in the Pacific, as found by Compton and Turner and by Gill. Certain small deviations can be explained by the longitude-effect of the cosmic radiation.

The influence of the aurora and of the magnetic disturbance of September 18, 1941 was studied with the model-C meter and with counter-telescopes, and a report on these phenomena was published.

*Studies on mesotron-disintegration and temperature-effect of cosmic radiation.* A dual telescope for continuous registration of the mesotron-component of cosmic radiation, devised and constructed at the Bartol Research Foundation by Dr. W. F. G. Swann in collaboration with Dr. Hess, has been in operation at Fordham Uni-

versity since March 1941. The unit consists of 108 Geiger-Müller counting-tubes in six trays mounted in a vertical counter-train; alternate trays are so connected for coincidence-counting that in reality there are two independent but interposed telescopes of three trays each, with 22 cm of lead between the trays and additional heavy screens for exclusion of side showers. Thus mesotrons coming in from the vertical direction are actuating both telescopes and are recorded by photographing the dials of two special recorders automatically every 2 hours. Reliability of operation is indicated by the constancy, within the natural fluctuations, of the counting-ratio between the upper and the lower telescope. Work with this telescope was begun in collaboration with F. A. Benedetto, S. J., and G. O. Altmann.

The mesotron-intensities obtained were compiled and reduced for 12- and 24-hour periods, and these values, after correction for the barometric effect, were correlated with temperatures at ground and at various levels of the daily atmosphere up to about 16 km, as supplied from the sounding-balloon flights at Lakehurst, New Jersey.

In collaboration with F. A. Benedetto it was shown that there is a continuously decreasing temperature-coefficient as one correlates mesotron-intensities at ground with temperatures at increasingly higher levels. This indicates that air-mass is more fundamental in these investigations, and that when average temperatures are taken by the spatial-average method, the temperatures at the higher levels have undue influence. With the method used by Benedetto and Hess, averages of temperature for various fractions of the atmosphere can be taken which are determined only by the mass of air in each fraction ("mass-temperature"). It was shown that then the temperature-coefficient is almost constant

for all fractions of the daily atmosphere up to four-fifths of the total air-mass. This corroborates the view that the so-called temperature-effect of cosmic rays is primarily an effect of atmospheric mass-distribution variations.

In collaboration with F. A. Benedetto and G. O. Altmann, the changes of mesotron-intensity with change in the average height of the center of gravity of the atmosphere were studied. From the coefficient of displacement derived therefrom, the mean range of life and mean lifetime of the mesotrons at sea-level were calculated.

A complete description of the dual telescope is given in the March 1942 issue of *Physical Review*. In this paper, which gives further results, it is shown that the temperature-coefficient of cosmic radiation varies as  $dz/dT$  (change of height of an atmospheric layer with temperature), when increasing fractions of the atmosphere, up to four-fifths of the total atmosphere, are taken. The assumption that mesotrons are produced throughout the atmosphere according to the distribution of the air-mass leads to a mean lifetime of the mesotrons at rest rather smaller than that obtained by other methods. These measurements are being continued by F. A. Benedetto, S. J.

*Gish-Hess ionization-meter.* In a theoretical study it is shown that, if one computes the ionization produced by gamma rays from radioactive substances in rocks and soil from figures given recently as average values for representative classes of rocks, the expected ionization turns out considerably smaller than that actually observed by placing ionization-vessels over land and over water. Two methods were developed theoretically which make it possible to determine simultaneously the residual ionization, the effect of cosmic radiation, and the effect of gamma rays from

the soil or from rocks (local radiation), and to separate these components of the total ionization.

Comparison of ionizations determined by one of these methods with values computed from given figures of radioactive material in well defined rocks is planned, and the experimental equipment for this work was constructed by the Department of Terrestrial Magnetism of the Carnegie Institution of Washington. The author acknowledges the valuable aid of the Director, the Assistant Director, and their associates in the Department during this work.

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#### STUDIES OF COSMIC RAYS

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During the year ending June 30, 1942, Dr. Johnson and his associates have continued investigations of the composition of the cosmic radiation in the lower atmosphere and of the processes of interaction of cosmic rays with matter. All the experimental studies during this period have

been made with a large Wilson cloud-chamber, fitted with various lead absorbing screens and arrangements of coincidence-counters. With this instrument 42,000 photographs have been taken and analyzed. The analysis of a part of these was reported last year. Although the analysis is now completed, the final conclusions cannot yet be announced.

Out of all the 42,000 photographs taken with the large chamber, only one showed a mesotron reaching the end of its range within the gas in the chamber. From measurements of the curvature and range of this particle, its rest-mass has been estimated as 75 times that of an electron. The particle was negatively charged and gave no indication of having disintegrated. It is interesting to note that the three or four disintegrations of mesotrons which have been observed in cloud-chambers have all been of positive rays. The present photograph represents the third negative particle observed to have stopped in the gas of a Wilson chamber.

Much attention during the past year has been devoted to the construction of a large high-pressure Wilson chamber of novel design. This chamber has been operated with controlled expansions at a pressure of 32,000 pounds per square inch. Good photographs of cosmic rays have been made with the chamber operating at a pressure of 400 pounds per square inch, and visible tracks accompanied by undesirable fog have been observed at 800 pounds per square inch. Now that the problems associated with the control of the expansions are solved, it is hoped that other troubles may soon clear away. This chamber will give a gaseous stopping power equivalent to 1 cm of lead, and it is anticipated that many examples of tracks will be found showing some of the rarer but highly interesting events of cosmic-ray absorption.

*Personnel.* Because of other requirements on Dr. Johnson's time, the work during this period has fallen almost wholly upon Messrs. R. P. Shutt and Sergio de Benedetti. They have had the assistance, from January 1 to June 30, 1942, of Martin H. Hornstine.

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#### COSMIC-RAY INVESTIGATIONS

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The cosmic-ray investigations carried out from July 1, 1941 to June 30, 1942, with the aid of funds made available through the Carnegie Institution of Washington, are set forth below.

*Cooperation with United States Antarctic Service.* The cosmic-ray data obtained on the United States Antarctic Expedition were analyzed. The observational program was divided into several sections. The first of these was the long-term study of the cosmic-ray intensity in Little America through the recordings of two meters during most of the antarctic winter of 1940. The resulting corrected daily means of cosmic-ray intensity were computed. These showed a decrease of intensity during only one of five magnetic storms recorded. This is noteworthy in view of the better correlation shown between magnetic storms and cosmic-ray intensity in temperate latitudes, but is understandable because of the unique character of the geomagnetic field in high latitudes. From

the compilations for an external temperature-coefficient it was found that the fluctuations in the cosmic-ray intensity correlated somewhat better with the changes in the temperature of the upper atmosphere than with those at sea-level. This condition was due to the large inversions of temperature occurring near the surface of the polar ice during the antarctic winter, as a result of which the temperatures at the surface in the Antarctic are not always indicative of the mean conditions in the air-mass overhead. This observation accords well with the view that the penetrating particles in the cosmic-ray radiation are produced at levels in the upper atmosphere, the variations in which levels are determined by the mean air-mass temperatures. Further analysis of these data is still in progress.

On the return trip from Antarctica a meter was operated continuously on board ship. An excellent run through far southern latitudes was obtained, comparable with that obtained on the voyage to Little America the previous year. It was found that the cosmic-ray intensity continued to increase slowly with increasing southerly latitude south of the familiar knee in the curve, but that this increase could be attributed to a decrease in the average external temperature. When an external temperature-coefficient was applied to the data, the curve at all latitudes south of New Zealand was sensibly flat. The fact that it was possible to use an external temperature-coefficient indicates that the air-mass conditions over the ocean in this region are fairly uniform and not characterized by such large temperature-inversions as were found over the ice.

*Study of nuclear dissociations produced by cosmic rays.* The processes by which cosmic rays produce neutrons and protons through nuclear dissociations were studied at several elevations. The neutrons were

investigated by using a neutron-counter together with cadmium absorbers and a shield of water, which permitted an evaluation of the number of neutrons in the thermal energy-range to be made. The protons produced by the radiation were studied with the aid of a methane counter. These experiments permitted the numbers and rates of production of each to be determined. These rates could then be compared with the other cosmic-ray variables at each altitude. The rates of production of neutrons and protons were found to increase with altitude faster than the total intensity of cosmic radiation and at about the same rate as the soft (electronic) component. Although the total number of neutrons appeared to be considerably greater than the number of protons, when account was taken of the much greater range of the neutrons and of the lower efficiency of the detection of neutrons, it was found that neutrons and protons are produced by the cosmic radiation at roughly the same rate. In this connection it must be recalled that protons and neutrons are present in approximately equal numbers in the nuclei of the light elements studied, that they are bound to these nuclei by energies which though slightly different are of the same orders of magnitude, and further that the energy of the entity producing the disintegration is large as compared with these binding energies. Thus cosmic rays are providing a new tool for the investigation of nuclear structure.

The observations led to the hypothesis of a possible connection between the process of production of neutrons and protons and cosmic-ray showers, namely, that the dissociation producing these particles may be produced by the photons which are present in abundance in the soft component. An experiment was designed to test this hypothesis. The apparatus was

arranged to count those discharges of neutron-counters and of cosmic-ray-shower counters which were coincident in time. The test was made with and without the cadmium shield which absorbs slow neutrons. This experiment gave a positive result indicating that a large percentage of the neutrons were associated with cosmic-ray showers, thus lending support to the suggestion that they are in all probability produced by the photons present in the radiation. These experiments were performed at several elevations, namely, at Swarthmore, in Denver, and at the Cosmic-Ray Laboratory on the summit of Mount Evans.

*Personnel.* The reduction of the cosmic-ray data obtained in the Antarctic was done by Dana K. Bailey. The records were measured under his supervision by Ernest K. Smith. Correlation-coefficients and dependences on pressure and temperature were computed by Robert A. Taylor. Eric T. Clarke assisted with the nuclear-disintegration experiments made on Mount Evans. It is a pleasure to acknowledge the cooperation of these and other collaborators.

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#### STUDIES OF COSMIC RAYS

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During the year July 1, 1941 to June 30, 1942, the research time and energies of the whole physics staff at the California Institute of Technology were devoted almost entirely to war problems. Nevertheless, so important cosmic-ray results have seemed to be in process of appearing from the projected program of experiments that some time has been stolen by a few of the workers in that field to push forward in three most significant and promising directions, namely: (1) in the testing in new latitudes by Millikan, Neher, and Pickering of their hypothesis as to the origin of cosmic-ray energies; (2) in the completion by Anderson and his students of their 60-cm high-resolution cloud-chamber for the more accurate study of the properties of mesotrons and the beginning of cloud-track measurements with it; and (3) in the improvement by Neher, Pickering, and Stever of cosmic-ray Geiger counters and studies of the mechanism of such counters.

*Tests by Robert A. Millikan, H. Victor Neher, and William H. Pickering, in Mexico and the United States, of the predictions of their hypothesis.* (a) Tests in

Mexico: These authors had predicted that since their hypothetical silicon-annihilation rays should have enough energy (13.2 billion electron-volts) to get through the earth's magnetic field at the geomagnetic equator in Peru, though not in India, there should be found at sea-level in the Americas a very long plateau of uniform, vertical cosmic-ray intensities extending north from Peru clear up to about the magnetic latitude of Victoria, Mexico (magnetic latitude,  $\Phi=32^{\circ}8'$  north). There the strong band due to the annihilation of the oxygen atom (computed energy 7.5 billion electron-volts) should first begin to be able to break vertically through the earth's magnetic field.

To test this quantitative prediction, the observers fitted out a truck as a radio laboratory and in December 1941 drove it as far south in Mexico as they could, namely, to Acapulco. There they made careful measurements on the vertically incoming rays both at sea-level and at all altitudes up to near the top of the atmosphere.

Both of the foregoing types of measurement (those taken at sea-level and those taken by integrating, with the aid of instruments taken up in balloon flights to very great heights, all the incoming cosmic-ray energy at all altitudes) revealed, as predicted, no increase whatever between the latitude of Acapulco ( $\Phi=25^{\circ}8'$  north) and that of Valles, 375 miles farther north. The upper-air measurements actually showed at Valles a small decrease, which was, however, inside the limits of instrumental uncertainties.

But in going from Valles to Victoria ( $\Phi=32^{\circ}8'$  north), a distance of but 112 miles, there was found a sudden, unambiguous rise in both the sea-level vertical intensity and the total integrated vertically incoming cosmic-ray energy. These findings were, then, in excellent agreement with the predictions of the theory as to the

approximate latitude at which the cosmic rays due to the annihilation of oxygen atoms should first begin to appear as the observer travels north in the Americas from the magnetic equator.

A further check on the theory was found in the following situation. If there were any sort of continuous distribution of the incoming cosmic rays with incident energy, then, since the earth's magnetic field is stronger in India than in Mexico, the intensity of the vertically incoming rays should be greater in Acapulco, Mexico ( $\Phi=25^{\circ}8'$  north) than in Peshawar, India ( $\Phi=25^{\circ}$  north). But the hypothesis denied the possibility of this result. Five different flights were made in Acapulco to test this point. The best of these flights gave practically the same vertical cosmic-ray intensity as that found in the observations taken in Peshawar in 1940. The mean in Acapulco was slightly lower than in Peshawar, though not enough so to be outside the limits of instrumental uncertainty.

(b) Tests in the United States: Again in driving the truck-laboratory from the latitude of Victoria, Mexico ( $\Phi=32^{\circ}8'$  north) to that of San Antonio, Texas ( $\Phi=38^{\circ}4'$  north) and Pasadena, California ( $\Phi=40^{\circ}7'$  north), where the vertical sea-level intensities were found to be the same, the hypothesis required that at the two last latitudes the annihilation-rays both of oxygen atoms and of nitrogen atoms should be added to the annihilation-rays of silicon atoms, as measured in Peshawar in India in 1940 and in both Acapulco and Valles in December 1941. The observations both of sea-level intensity and of integrated energy revealed the predicted large increase between these latitudes (over 30 per cent).

The observers also made in March 1942 preliminary and less dependable measurements of the changes in integrated energy

in going from Pasadena, California ( $\Phi = 40^{\circ}7'$  north) to St. George, Utah ( $\Phi = 45^{\circ}$  north). Their single flight at St. George showed an increase of 18 per cent over that at Pasadena. This increase they attribute to the entrance between these latitudes of the carbon-atom-annihilation rays.

In going from St. George to Pocatello, Idaho ( $\Phi = 51^{\circ}$  north), a change of  $6^{\circ}$  in contrast with the change of  $4^{\circ}$  from Pasadena to St. George, they found in their only measured flight no increase—a result required by their hypothesis, since there are no abundant atoms of atomic weight between that of carbon and that of helium.

(c) Discovery of large variability of helium-annihilation rays: Within the year (in August and September 1941) these same observers made a series of accurate measurements of total incoming cosmic-ray energy as measured by electrosopes, rather than by vertical counters, sent to close to the top of the atmosphere at Bismarck, North Dakota ( $\Phi = 56^{\circ}7'$  north), Omaha, Nebraska ( $\Phi = 51^{\circ}3'$  north), Oklahoma City, Oklahoma ( $\Phi = 45^{\circ}$  north), Fort Worth, Texas ( $\Phi = 41^{\circ}6'$  north), and San Antonio, Texas ( $\Phi = 38^{\circ}4'$  north). These accurate measurements brought to light the notable fact that whereas the total incoming energy at San Antonio was the same as that measured there in 1935, the helium-annihilation rays coming in at Bismarck, measured within a week of the measurements at San Antonio, showed at the top an increase of at least 30 per cent over measurements of the same sort made there in 1938. The soft rays due to helium are, then, very much more variable than are the hard rays due to the heavier and very much less abundant atoms. Whether this variability in the softest component of the incoming rays is due to changes in the magnetic field of the earth or of the sun or

represents a more fundamental variability in the rate at which helium atoms are being transformed in outer space into cosmic rays is yet to be determined.

*Work of Carl D. Anderson, Leon Katz, and R. V. Adams on a high-resolution cloud-chamber for the accurate determination of the properties of mesotrons.* The large magnet-cloud-chamber apparatus at the California Institute has been in operation during the year July 1941 to June 1942. In all only about 1000 photographs were taken, as most of the time was spent in improving the operation of the apparatus, principally with regard to decreasing the small distortions of the tracks due to motions of the gas. These motions are the most important factor in limiting the accuracy of the energy-measurements. Several different designs of the moving diaphragm have been tested, the timing of the illumination has been improved, and better temperature-control has been achieved. At present it is possible to measure energies in good tracks up to 20 billion electron-volts with fair precision. A system for measuring the tracks by re-projecting the images and thus eliminating all lens distortion has been completed.

*Improvement in cosmic-ray Geiger counters and studies of the mechanism of such counters, by H. Victor Neher, William H. Pickering, and H. G. Stever.* As an offshoot of the development of high-altitude Geiger-counter observations, these workers made fundamental studies in the operation of Geiger counters. These led directly to the development of a new type of counter, in which the central wire is provided with glass beads which isolate the counter into sections, and which thereby not only permits coincidence-measurements with a single counter, but illuminates from a new angle the whole theory of counter-action.



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## MASS OF THE MESOTRON

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On July 1, 1941, an expedition to the summit of Mount Evans (14,125 feet) was already under way. This work and its development had been made possible through the support of the Rumford Fund for the Study of Radiation of the American Academy of Arts and Sciences, the Penrose Fund of the American Philosophical Society, the Fund for Astrophysical Research, and the John Simon Guggenheim Memorial Foundation. Preliminary reports on six months' examination of over 20,000 photographs of cosmic rays passing through a large Wilson cloud-chamber obtained on that expedition were published in *Physical Review* (see bibliography); a complete paper on the results is in preparation. Many valuable suggestions in interpreting the results were given by Professor J. R. Oppenheimer.

CALIFORNIA INSTITUTE OF TECHNOLOGY, Pasadena, California. *Cooperative researches at the Seismological Laboratory*. (For previous reports see Year Books Nos. 37 to 40.)

One part of the research program at the Seismological Laboratory at Pasadena is concerned with local earthquakes, that is,

As a result of this work, and with the continued financial support of the organizations above mentioned and of the Carnegie Institution of Washington, plans were made to measure the mass of the mesotron with a cloud-chamber and a magnetic field. A new cloud-chamber was made following techniques developed by Professor R. B. Brode and his students at the University of California, and utilizing some apparatus obtained by the Department of Physics of the University. The new cloud-chamber is used with a large pair of Helmholtz coils. These coils are supplied by storage batteries with a large current at the moment of expansion and photography of the cloud-chamber. Statistical treatment of the data obtained through the earlier random photographs at the summit of Mount Evans indicates that a large number of slow mesotrons may be observed whose ionization is measurably denser than that of a high-energy electron.

Dr. Carl E. Nielsen, of the University of California, assisted in this research and in preparation of apparatus, and after the transfer of Dr. Powell to war-research activities, on June 10, 1942, took full charge of the investigation. After tests at Berkeley, which showed that the whole apparatus functioned as expected, he reached the summit of Mount Evans with practically all the equipment, mounted in a trailer.

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those originating in southern California and adjacent territory. The purposes of this part of the program include the de-

termination of the following: the seismicity of southern California and of its different parts; the relations of earthquakes to the faults known in the region; the origin and nature of shocks not originating on the more important faults but within the great crustal blocks; the depths of the origins of shocks; the accelerations, periods, and other elements in local earthquakes, desired by engineers as data for computing strengths of structures to be built in the region; and the nature of the forces causing the mountain making and the earthquakes in this part of the state. Another part of the activity of the Laboratory deals with broader geophysical and tectonic problems, for which the data from both local and distant earthquakes are essential. Among such problems are the thickness and the nature of the earth's so-called crust in the different parts of southern California, the thickness of the crust where deformed by past mountain making, and the quantitative relations of such elements of earthquakes as their magnitudes, intensities, and accelerations.

The largest amount of data obtainable, in the form of precise seismographic records, is none too extensive for the successful prosecution of the researches on the problems mentioned above. For this reason the instruments at the Pasadena laboratory and the seven outlying stations in southern California are kept in continuous operation. After many years' effort, they now write very accurate records and permit time determinations of the phases of earthquakes to a small fraction of a second. The Laboratory's records now, together with those obtained by the University of California in central California, those made by the U. S. Bureau of Reclamation at Lake Mead, and those written by the U. S. Coast and Geodetic Survey at Tucson and on their strong motion instruments at numerous localities in the Southwest,

give a better set of data on every earthquake occurring in the Southwest than has ever been available before. The systematic registration of shocks in this region can continue for a long time to come before the effort and expense will begin to yield decreasing returns both on the practical and on the theoretical side of seismology and geophysics.

A full program of registration has been continued during the year at the Pasadena laboratory and at the seven outlying stations, including Palomar.

Though equipment has been maintained and some improvements have been made at some of the stations, instrument design and construction are in abeyance for the duration of the war. Dr. Benioff and his mechanical staff are engaged on government research and construction, utilizing the shop facilities of the Laboratory.

Mr. Robert E. Rogers accepted a commission in the U. S. Navy and was granted a leave of absence to begin July 15, 1942. Miss Patricia Hawkins begins service as an assistant in the measurement of records on July 1, 1942. Miss Catharine McCollum will take charge of the photographic and related work in the Laboratory on September 2, 1942.

*Crustal structure.* The earth is made of concentric shells of different types of rock material. The outermost shell, or crust, consists of an upper or granitic layer, which forms the continents, and deeper layers of comparable thickness made of basic igneous rock. The average thickness of the crust is about 35 or 40 km. The detailed nature of this crust has been under vigorous investigation at the Seismological Laboratory during the past year. Answers were desired to such questions as, What is the thickness of the two parts of the crust under southern California, and under mountains? Do mountains have "roots," and what happens when

mountains are formed by telescoping of the crust, with reference to the thickening of the granitic plate or upper part of the crust and with reference to the basaltic or lower part? Do the lower surfaces of these layers bulge downward, each into the heavier layer next below, in order to support the upward bulge of the granitic layer which we recognize on the surface as a mountain range?

The investigation of the foregoing and related questions during the current year has yielded extensive results, partially embodied in three papers already in course of publication and in other manuscripts in preparation. Two of these papers, by Dr. Beno Gutenberg, are "Earthquakes and structure in southern California" and "Seismological evidence for roots of mountains."

Some of the important new conclusions, with the evidence therefor, brought out in these two papers are as follows: The granitic layer in southern California is about 18 km. thick, and the basaltic layers beneath it, forming the lower part of the crust, are about 22 km. thick, giving a total thickness of about 40 km. for the crust in this region. In southern California both the thickness of the granitic layer and the total thickness of the crust are considerably less than the average thickness under Europe, and it appears that the basic layers forming the lower part of the crust are of somewhat different composition from those under Europe. All the earthquakes in southern California apparently originate near the base of the granitic layer, that is, at a depth of about 18 km. Under the Sierra Nevada the total thickness of the crust is considerably greater than in other parts of southern California, being about 60 km., but, surprisingly enough, the granitic layer is no thicker than in surrounding areas. The basaltic layers forming the lower part of the crust have thickened

from about 22 to about 42 km. This thickening of only the lower layers of the crust under the Sierra Nevada is in marked contrast with conditions in the Alps, where the main thickening occurred in the granitic or uppermost layer of the crust. In the Alps the total thickness of the crust is also about 60 km., but the granitic layer was thickened to about 40 km. Outside the Alps, in Yugoslavia, the granitic layer, below about 4 km. of sediments, is about 13 km. thick, and the underlying basaltic layers about 25 km., giving a total of about 42 km. In New Zealand the granitic layer is only about 10 km. thick, and the basaltic layers about 20 km., so that the total crustal thickness is only about 30 km.

It was possible also to obtain some data on the horizontal extent of the Sierran root or thickened part of the crust. It does not extend much east of the east base of the present upfaulted range, and it does not extend westward beneath the San Joaquin Valley. It is best developed under the highest part of the range, and does not extend southward under the Tehachapi Mountains, which are sometimes considered to be the southern part of the range.

In the Alps the mountain making, folding, and faulting occurred after the great granitic batholiths were emplaced; in the Sierra Nevada probably the reverse is true for the great Jurassic mountain making. The question whether this explains why the granitic layer is greatly thickened under the Alps but not under the Sierras should be further investigated.

Some progress has also been made in determining why waves arriving at a given seismographic station arrive "too early" or "too late." These differences in travel time appear to be due to two causes: differences in paths through the deeper layers, which vary in thickness, and differences in the other rocks near the station through

which the sedimentary waves pass in the last part of their paths.

It has also been found that whereas all the larger shocks occur on the more important faults, many of the minor shocks occur on minor faults within the major fault blocks. This probably means that the shearing forces involved in mountain making are in part relieved by slips on the major faults and in part by internal deformation of the major fault blocks into which the region being deformed has been cut by the major faults. If this assumption is correct, this is a very important and fundamental fact in tectonics or structural geology.

In the course of the investigations on the above problems other results of very fundamental nature were obtained. These are being published in a joint paper by Dr. Beno Gutenberg and Dr. Charles F. Richter, entitled "Earthquake magnitude, intensity, energy, and acceleration," to be issued in the July 1942 number of the *Bulletin of the Seismological Society of America*. This paper sets forth the relations of the important elements in earthquakes: the magnitude, which may be said to be measured by the size of the area shaken; the intensity or vigor of the shaking; the total energy released in the earthquake; and the maximum accelerations in the shock. Equations for relating quantitatively all these elements in an earthquake are developed for the first time.

*Conspectus of seismologic stations.* In the study of past earthquakes it is important to know what seismological stations were in existence at different times. During the year Mr. H. O. Wood completed and published "A chronologic conspectus of seismologic stations," containing data for more than 800 stations which have been in operation for longer or shorter periods in different parts of the world.

*Southern California earthquakes.* A

number of important earthquakes occurred in southern California during the year. Most of them provided valuable additional data for Gutenberg's study of travel times and structures.

On September 14, 1941, the central Sierra Nevada region was shaken by a group of shocks, the largest of which was of magnitude 6. Many rock slides, some of which were large, were started in the range. Gutenberg determined an epicenter on Owens River in Long Valley. Aftershocks were very numerous; a large one (magnitude 5.5) occurred as late as December 30.

On September 5 a shock of magnitude 5 occurred on or close to the San Andreas Fault in Cuddy Valley. Gutenberg's study shows that earlier shocks in the same region certainly originated north of this one, so that there must be activity north of the visible rift.

On October 22, a shock of magnitude 5, originating on the Inglewood fault zone, caused some damage at Gardena. An offset occurred on a subsurface fault in the near-by Dominguez Hill oil field. The seismological evidence shows that the point of initial rupture in the earthquake was at the usual depth (about 15 to 18 km.), and not under the fracture in question; the displacement on this fracture must be considered as having been triggered by the main earthquake. The secondary earthquake source thus produced seems to have added to the local intensity in the immediately surrounding area.

On November 14 a larger shock (magnitude 5.5) originated farther to the southwest; this shock produced no further effects in the Dominguez field, but caused extensive damage at Torrance and Gardena.

On February 1, 1942, there was a long series of minor shocks (magnitudes up to 4.5) in the Lucerne Valley area north of the San Bernardino Mountains.

On March 5 a shock of magnitude 5 originated still farther east, in the Pinto Mountains. Exact study of a shock so far east might have provided much valuable information on the structures transitional between those of the Coast Ranges and of the Colorado Plateau; but Gutenberg found that the comparatively large distance from all the more sensitive stations, and the generally unfavorable location, renders any conclusions uncertain. The later installation of more sensitive instruments in the Lake Mead area may make it possible to carry out complete investigations on future shocks in this interesting transitional region.

Of the many distant shocks recorded, at least fifteen were of magnitude 7 or over (major earthquakes). The great Atlantic shock of November 25, 1941 approached magnitude 8.5, and thus may have been the largest earthquake since 1922. At Pasadena the surface waves were recorded with amplitudes up to 2.5 mm. (actual displacement of the ground).

*Research on sound waves.* Research was continued on the propagation of waves in the atmosphere, applying the laws of elastic waves used in seismology and utilizing equipment specially constructed at the Seismological Laboratory for the purpose. A short paper was published by Gutenberg and Benioff on some of the results secured.

During the year the following papers were presented: At the meetings of the Geological and Seismological Societies of America at the California Institute of Technology on April 17-18, 1942: "Earthquakes and structure in southern California," by Beno Gutenberg; "Technique in calculat-

ing epicenters," by Charles F. Richter; "Determination of epicenters and travel times in southern California," by Beno Gutenberg; "Earthquake magnitude, intensity, energy and acceleration," by Beno Gutenberg and Charles F. Richter; "Gouge is not positive fault evidence," by John P. Buwalda. At the April 1942 meeting of the Mathematical Society at Berkeley: "Mathematical questions in seismology," by Charles F. Richter.

Both Dr. Gutenberg and Dr. Richter have devoted a part of their time during the year to defense research and instruction.

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UNIVERSITY OF PITTSBURGH, Pittsburgh, Pennsylvania. *Microcalorimetric studies of the thermal properties of dilute solutions.* (For previous report see Year Book No. 40.)

These studies were started in September 1940 and have been carried on by Dr. William E. Wallace under the direction of

Dr. A. L. Robinson, of the Department of Chemistry of the University of Pittsburgh, and in cooperation with Dr. R. E.

Gibson, of the Geophysical Laboratory of the Carnegie Institution of Washington.

Measurements of the heats of solution and dilution of calcium sulfate dihydrate in sodium chloride solutions have been completed. Results of this investigation were presented before the Physical Section at the American Chemical Society meeting in Memphis, in April 1942.

The heats of dilution of aqueous glycine solutions have been investigated. Results of this study have been prepared for publication.

The heats of dilution of some lanthanum salts have been under investigation. Satisfactory data have been obtained using lan-

thanum chloride and lanthanum sulfate. These results have also been prepared for publication.

The microcalorimeter used in the above studies has undergone alteration of such nature that nonaqueous solvents can now be accommodated. At the present time (June 1942) work is in progress involving measurements of the heats of dilution of sodium chloride in ethylene glycol.

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JOSEPH C. BOYCE, Massachusetts Institute of Technology, Cambridge, Massachusetts.  
*Research in the spectroscopy of the vacuum ultraviolet.* (For previous reports see Year Books Nos. 38 to 40.)

This research, supported for three years by grants from the Carnegie Corporation of New York to the Carnegie Institution of Washington, continued into its fourth year on an unexpended surplus from previous years. Early in the year covered by this report it became apparent that the demand for trained research workers and for shop facilities would soon put a stop to all research work not directly contributing to preparations for war. It was therefore decided, before the experienced personnel of the project should be scattered, to discontinue the program of photographing additional spectra and to proceed with the reduction of observations on some representative spectra. In this way it would be possible to evaluate the results attained to date in this program and in the parallel Works Progress Administration program for the measurement of the spectra.

The most reliable wave-length standards between  $\lambda_{2000}$  and  $\lambda_{1300}$  are those of Cu II determined by Shenstone (*Philos. Trans.*

*Roy. Soc., A*, vol. 235, pp. 195-243, 1936) and of Fe II by Green (*Phys. Rev.*, vol. 55, pp. 1209-1217, 1939) and by Edlén (unpublished data in substantial agreement with Green but containing additional lines). These are each based on combinations between spectroscopic terms which can themselves be located from lines in the longer wave-length region of the spectrum. By a happy relation (J. C. Boyce, *Rev. Mod. Phys.*, vol. 13, pp. 1-57, 1941; see especially p. 21) between wave length and wave number, at various wave-length regions, the wave-length accuracy of these standards in the short wave-length region is somewhat greater than that of the longer wave-length lines used in determining the term values. Most of the copper lines arise from high levels in the copper ion, not ordinarily excited in sparks, and require Schüller cathode excitation. Furthermore, there are considerable gaps between standards in each of these systems.

Mrs. Lyman therefore undertook a critical study of all available exposures of cop-

per (spark and Schüler tube excitation), iron (spark excitation), and mixtures (in a pressed-powder electrode) of copper and iron (spark excitation), as well as of sparks of silver and of silver-copper and silver-iron mixtures. Six exposures of copper, two of iron, and five of an iron-copper mixture were selected which had all been measured by means of the Harrison automatic comparator (*Jour. Opt. Soc. Amer.*, vol. 25, pp. 169-178, 1935). On every plate examined, the values for the wave lengths of the lines used were checked as to accuracy in reading the microphotometer films and in the arithmetical averaging of the six individual readings of each line. In most cases only the values of the standards on the plates were examined. On one Fe plate and four Cu plates, all the lines were checked.

*Fe and Fe-Cu.* Calibration curves using Edlén's Fe standards as true values were drawn for the standards from two Fe plates. The wave lengths of the lines were corrected from the curves. Each of these two plates was remeasured on the automatic comparator. New calibration curves were drawn and the values of the standards read from the curves.

Several Fe calibration curves were obtained from Fe-Cu plates. The corrected values of the Fe standards from all the Fe and Fe-Cu measurements were assembled and averaged, and the final values corresponded so closely to Edlén's values for the standards that his list with the exception of a few lines was adopted as the Fe standard list. Edlén's Fe standards did not uniformly represent the range desired, however, so the plates were examined for additional lines which might be used as standards. Several values for the lines picked out were obtained from the respective correction curves for those plates. The averages of these values were added to the Edlén Fe standard list as possible addi-

tional Fe standards, giving a range of standards from  $\lambda 1400$  to  $\lambda 2050$ . Some of the new standards were Fe II and some Fe III lines.

*Cu and Cu-Fe.* Since most of Shenstone's calculated Cu lines appeared only in the Schüler tube excitation of Cu and not in the spark spectra of Cu, it was necessary to pick out spark Cu lines which could serve as standards on spark plates. The values of the proposed Cu standards were read on Cu-Fe plates and corrected by means of the Fe calibration curves. The Cu standards were read from Cu plates and calibration curves for the Cu standards drawn. The averages of all the possible values of the Cu standards were obtained (two Cu plates being remeasured and read as additional checks). A list of Cu spark standards was then compiled which covered the range from  $\lambda 1300$  to  $\lambda 2000$ . Some of the lines were Cu II and some Cu III.

Four Cu Schüler tube plates were also read and the measured wave lengths of the standards corrected from calibration curves containing many of Shenstone's calculated Cu lines.

*Ag, Ag-Fe, and Ag-Cu.* The Fe and Cu standards were then used in an attempt to determine some Ag standards. Gilbert's work on Ag III (*Phys. Rev.*, vol. 47, pp. 847-850, 1935; vol. 48, pp. 338-342, 1935) was used as a comparison with the new measurements. A term array of Ag III based on the new measurements from Ag-Fe plates between  $\lambda 1600$  and  $\lambda 1700$  and between  $\lambda 1800$  and  $\lambda 1950$ , and on Gilbert's values above  $\lambda 2050$  was attempted, but the results were very unsatisfactory and in very poor agreement with Gilbert's values. The Ag-Cu plate gave a poor Cu calibration curve, and since there were many Ag-Cu blends, the attempt to obtain Ag standards was abandoned for the time being.

Table 1 presents the previous and the added wave-length standards in the range from  $\lambda_{1309}$  to  $\lambda_{2041}$  in both copper and iron, arranged in order of wave length. The accuracy of the older data, based on the combination principle, is believed to range from 0.002 to 0.004 Å. The newer data are inherently somewhat less accurate, but an estimate of 0.005 Å as their probable error seems reasonable.

Titanium was selected as an element whose spectra in the vacuum ultraviolet were simple and fairly well understood, but for which the published wave-length measurements (H. N. Russell and R. J. Lang, *Astrophys. Jour.*, vol. 66, pp. 13-42, 1927; H. N. Russell, *ibid.*, vol. 66, pp. 283-328, 1927) were not of high accuracy. Miss Pitkin assembled and checked wave-length data from representative exposures of titanium and of mixtures of titanium with iron and copper. The wave-length standards listed in table 1 were used in the reduction of these measurements, as slight corrections to the data given by the automatic comparator. About 60 lines of Ti III between  $\lambda_{1282}$  and  $\lambda_{1948}$  were fitted into a term array, following Russell and Lang, but permitting a considerably more precise determination of term values. About 10 lines which had not been given by Russell and Lang could now be classified. The multiplet of Ti II in the vicinity  $\lambda_{1910}$  was remeasured, as were a few lines of Ti IV. Publication of these results has been deferred until there is opportunity to extend the measurements to the region of shorter wave lengths.

The precision of these data, as evidenced by the accurate fit into term arrays, as well as by the check with Edlén on the iron measurements, gives evidence as to the reliability of the large amount of data contained in the collection of spectra. When work is resumed after the war, the observational program should be directed to-

ward obtaining spectra from vacuum sparks, to give somewhat higher excitation than has been obtained in the previous observations. This will assist in assigning hitherto unclassified lines to the appropriate stage of ionization and will extend the range of the measurements down to perhaps  $\lambda_{500}$ . At the same time the program for the reduction of observations should be considerably expanded. The collection of films from the Harrison automatic comparator will be very useful, as will many of the W.P.A. readings and averagings from these films. As would be expected of such results obtained by untrained workers, the recent studies have shown that this computational work has varying reliability and must be carefully checked.

An important spectroscopic paper published during the year by B. Edlén and P. Swings is based in part on data obtained in 1937 with the Carnegie spectrograph. These investigators have measured the third spectrum of iron in the region from approximately  $\lambda_{500}$  to  $\lambda_{6500}$  and have carried out a very complete term analysis. The measurements between  $\lambda_{2023}$  and  $\lambda_{1382}$  (some 400 lines) were based exclusively on plates taken by Edlén while he was a guest in this laboratory. The same plates gave 150 additional lines attributed to Fe III in the regions up to  $\lambda_{2338}$  and down to  $\lambda_{1017}$ , regions in which the observations with the Carnegie instrument were overlapped by those with a quartz-prism spectrograph and with a grazing-incidence vacuum spectrograph, respectively.

The analysis of Fe III by Edlén and Swings is the most complete one ever carried out for the third spectrum of a metallic element. Of the 34 theoretically possible terms of the  $3d^6$  configuration, 32 have been found. Of the 74 theoretical levels for  $3d^6 4s$ , only 10 high-lying levels



TABLE I

PREVIOUS AND NEW WAVE-LENGTH STANDARDS IN IRON AND COPPER

INT. (ARBI- TRARY SCALE)	SPECTRUM	Fe		Cu		INT. (ARBI- TRARY SCALE)	SPECTRUM	Fe		Cu	
		Edlén	New	Shenstone	New			Edlén	New	Shenstone	New
4	II	.....		1309.463		3	.....	.....		1588.542	
$\frac{1}{2}$	II	.....		1326.394		0	II	.....		1590.164	
$\frac{1}{2}$	II	.....		1329.654		3	.....	.....		1592.967	
3	II	.....		1337.544		2	.....	.....		1599.415	
4	II	.....		1339.463		2	II	.....		1602.387	
0	II	.....		1363.501		5	II	1610.922		.....	
4	II	.....		1367.952		5	II	1612.805		.....	
1	II	.....		1371.451		3	.....	.....		1621.695	
5	II	.....		1377.477		5	II	1623.090		.....	
3	II	.....		1393.126		5	II	1625.520		.....	
2	.....	1401.756		.....		4	II	1632.665		.....	
1	.....	.....		1403.722		5	II	1633.906		.....	
2	II	1405.605		.....		5	II	1637.398		.....	
4	II	.....		1407.160		5	.....	.....		1639.945	
4	.....	1413.685		.....		5	II	1640.150		.....	
3	.....	.....		1418.779		5	II	1643.576		.....	
1	II	1418.851		.....		4	II	1654.476		.....	
3	.....	1420.901		.....		5	II	1658.771		.....	
4	II	1424.714		.....		5	II	1659.479		.....	
3	II	1434.994		.....		5	II	1663.220		.....	
2	II	1442.746		.....		2	.....	.....		1665.563	
3	.....	1448.387		.....		4	.....	.....		1669.272	
3	.....	1456.464		.....		5	II	1673.466		.....	
3	.....	.....		1460.896		5	II	1674.254		.....	
3	.....	1463.196		.....		5	II	1674.715		.....	
2	.....	1472.040		.....		4	II	1676.854		.....	
4	II	.....		1472.399		6	.....	.....		1682.666	
3	.....	.....		1472.837		1	II	.....		1683.150	
2	.....	1478.112		.....		4	II	1685.952		.....	
3	.....	1489.918		.....		5	II	1686.454		.....	
2	.....	1498.288		.....		4	II	1686.690		.....	
3	.....	.....		1502.082		4	II	1689.832		.....	
3	.....	1506.897		.....		4	II	1690.755		.....	
2	.....	.....		1509.951		4	II	1691.272		.....	
3	.....	1522.685		.....		3	II	1693.935		.....	
3	II	.....		1532.124		5	II	1696.794		.....	
3	.....	1533.440		.....		4	II	1699.195		.....	
6	II	.....		1537.560		4	.....	.....		1704.052	
3	II	1548.694		.....		5	II	1708.621		.....	
5	II	.....		1549.202		6	II	1712.998		.....	
4	II	.....		1550.644		2	.....	.....		1713.335	
3	II	.....		1551.379		4	II	1716.576		.....	
2	II	1551.929		.....		1	II	.....		1717.72	
5	II	1558.538		.....		5	II	1724.853		.....	
5	II	1558.691		.....		5	II	1724.962		.....	
3	.....	.....		1561.788		5	II	1726.391		.....	
0	II	.....		1566.411		3	.....	1731.858		.....	
5	II	1566.821		.....		3	.....	.....		1732.976	
5	II	1568.017		.....		4	.....	1740.316		.....	
5	II	1569.674		.....		5	.....	.....		1751.216	
5	II	1570.244		.....		4	.....	.....		1754.994	
5	II	1573.826		.....		5	.....	1761.371		.....	
5	II	1574.769		.....		3	II	1764.117		.....	
5	II	1574.921		.....		1	.....	.....		1766.202	
2	.....	.....		1581.264		5	II	1772.512		.....	
1	II	.....		1583.683		2	.....	.....		1780.039	
5	II	1584.949		.....		4	II	1793.367		.....	
5	II	1588.288		.....		2	.....	.....		1798.737	

(Continued on following page)

TABLE 1—Continued

INT. (ARBI- TRARY SCALE)	SPECTRUM	Fe		Cu		INT. (ARBI- TRARY SCALE)	SPECTRUM	Fe		Cu	
		Edlén	New	Shenstone	New			Edlén	New	Shenstone	New
3				1826.317		4		1957.922			
4	II	1835.872				5		1960.302			
4	II	1846.574				4		1965.294			
4	II	1848.771				2	II			1970.489	
5	II	1860.052				4	III	1976.114			
4				1867.729		6	II			1979.947	
4	II	1876.836				4	III	1982.055			
5	II	1877.470				3		1986.399			
1	II			1882.240		6	II			1989.849	
5	II	1888.734				4	III	1989.957			
4		1891.501				4	III	1993.247			
3	III	1902.388				5	III	1996.405			
4	II	1904.790				6	II			2000.339*	
2	III	1912.905				5	II	2001.025			
2		1919.556				5	II	2011.348			
3		1924.517				4	II	2016.136			
5	III	1931.486				5	II			2017.60	
3	II	1935.299				4	II	2019.429			
4	III	1940.003				4	II	2021.399			
5	III	1943.459				4	II	2033.060			
5	II			1944.586		4	II	2037.089			
5		1950.323				5	II	2041.346			

\* Blend.

have not been found. Of the  $3d^5 4p$ , practically all theoretically possible levels corresponding to those found in  $3d^5 4s$  have been established. The final tables contain 320 levels and approximately 1500 classified lines.

A considerable extension by Edlén of the analysis of the second spectrum of iron (Fe II), using data from the same plates, is substantially completed and will be published in due course.

W. H. NEWHOUSE, Massachusetts Institute of Technology, Cambridge, Massachusetts.  
*Spectrographic studies of minor elements in minerals.* (For previous report see Year Book No. 40.)

Analytical work has continued on the variations of minor elements in mineral deposits. The qualitative work has been completed on the examples described in Year Book No. 40. In order to leave no gaps in the data, all the minerals present to the extent of 5 per cent and more have been hand-picked and separately ana-

Miss Pauline Pitkin continued as research assistant until February 1942, when she resigned to accept a position in war research. Mrs. E. R. Lyman, who joined the project in June 1941, resigned in December, also to do scientific work in connection with the war.

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lyzed. Mixtures containing the less abundant and particularly the fine-grained minerals were analyzed to make certain that all elements present in the mineral deposits were identified. Over 800 analyses have been made, with examination for approximately 50 elements in each.

Quantitative work has been completed

during the past year on the most widespread and abundant mineral, magnetite, and is now in progress on the feldspars and micas. Fifty magnetites from the varied geological environments selected for study were quantitatively analyzed for elements that showed some regularity in variation. These elements are zinc, nickel, cobalt, magnesium, vanadium, chromium, and strontium.

Some difficulty has been experienced in finding suitable internal standards for use in the quantitative work on these silicate minerals. This follows from the large variation in most of the main chemical elements present in the various members of

these groups. Further conclusions must await the analytical data now being obtained.

The results of work in cooperation with Dr. Clifford Frondel on the spatial distribution of minor elements in single crystals of galena ( $\text{PbS}$ ) and calcite ( $\text{CaCO}_3$ ) are described in a paper now in course of publication.

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## DIVISION OF PLANT BIOLOGY

*Central Laboratory located at Stanford University, California*

H. A. SPOEHR, *Chairman*

For many years it has been generally assumed that the process of photosynthesis is fundamentally the same in all plants. Although it has been realized that in some of the lower forms of plant life, such as the purple bacteria, certain differences exist, the view has been commonly held that the photosynthetic apparatus, and also the products which are elaborated through this apparatus, are the same throughout the plant kingdom. Very little regard has been paid to the fact that the great diversity of plant forms which possess the power of photosynthesis represents a tremendous variance in evolutionary history and in range of adaptability, and considerable difference in chemical composition. It is, moreover, somewhat difficult to conceive that the geological evidences of photosynthetic activity, presumably represented by deposits of petroleum and carbonaceous material, had their origin in the photosynthetic process as we know it to occur today. That all plants do not contain the same photosynthetic apparatus has now been demonstrated by the discovery in diatoms, brown algae, and red algae of chlorophylls and yellow pigments which are different from the corresponding pigments existing in higher plants. Whether or not this difference in the photosynthetic apparatus is reflected in differences in the products elaborated remains to be established.

Pigments absorb the radiant energy essential to the production of carbon compounds by autotrophic organisms. Thus far little has been learned about how this absorbed energy is utilized in the synthetic processes carried out in plants. It is not

known to what extent each of the several green and yellow leaf pigments participates in this natural production of organic matter. It is believed that much can be learned from comparison of the light-absorbing properties of the individual pigments with the effect produced in the plant by light of various wave lengths. Such comparisons are dependent upon preparation of the pure pigments and upon precise determination of their spectral absorption properties.

For comparative purposes it is desirable to study organisms that differ considerably with respect to the pigments of the photosynthetic apparatus. Indications that different varieties of photosynthetically active pigments occur in different classes of algae have made necessary a more exact investigation of the pigments of these organisms. Advances that have been made in this investigation have been due largely to improvement of the sensitive chromatographic adsorption method of analysis and to use of spectral absorption measurements. By these means it has been possible to establish that most of the higher plants contain the same green and yellow leaf pigments, and to determine the differences which exist in regard to the photosynthetically active pigments between the higher and lower forms of plant life. These discoveries have raised a number of important questions regarding the variability of the photosynthetic apparatus throughout the plant kingdom and the possible bearing of this on the nature of the products which are formed. These findings may also contribute to a more exact systematic classification of some of these organisms

on the basis of their pigment complex and to better understanding of the phylogenetic relations between various algae.

Diatoms are widely distributed both in marine and in fresh waters. In the open ocean these minute plants usually are present in quantities exceeding those of all other forms of plant life, and it is probable that the total production of organic matter by diatoms exceeds that by any other class of plants. These organisms also flourished in past ages, as is indicated by the many extensive deposits of diatomaceous earth, consisting of the siliceous cell walls of diatoms. There is some evidence that many petroleum deposits have originated in organic materials manufactured by diatoms.

Despite the importance of diatoms in the carbon economy of nature, relatively little specific information is available concerning their chemical composition or the nature of their metabolism. Apparently the storage products of photosynthesis in diatoms are largely oils or oil-like substances, in contrast with the carbohydrates usually stored by higher plants. The question arises: are these different products the result of different photosynthetic mechanisms in the two groups, or merely of differences in secondary metabolic reactions? Differences in the photosynthetic pigment systems support the view that there may be fundamental differences between the photosynthetic process in diatoms and the corresponding process in higher plants or green algae.

Methods have been devised and apparatus has been constructed for the growing of relatively large quantities of these organisms in pure culture. The investigations are planned to yield information on the components of the photosynthetic apparatus, the composition of the photosynthetic products, and the type of photosynthetic reaction which occurs in these or-

ganisms. They are particularly favorable material for the investigation of the influence of different environmental factors on photosynthetic and metabolic activities, for which higher plants are in many respects less suitable. In order to gain a sufficiently comprehensive view of these functions of plants it is necessary to obtain data from plants representing different stages in the evolutionary scale.

The usual conception of the photosynthetic reaction is that the carbon dioxide absorbed by an illuminated plant is converted completely into carbohydrates. Many experiments have demonstrated the increase of carbohydrates during photosynthesis, but none of them has shown that carbohydrates are the only substances produced. A clear-cut demonstration of whether or not carbohydrates are the only products of photosynthesis is of fundamental significance to the understanding of the chemistry of this process. If carbon dioxide is transformed quantitatively into carbohydrates by the photosynthetic reaction, then all other substances elaborated by the plant must arise from subsequent transformations of carbohydrates. This would automatically separate all the chemical reactions occurring in plants into two main groups: the photosynthesis of carbohydrates, and the conversion of carbohydrates into all the rest of the organic substances which may be found in plants.

Because of the fundamental nature of this postulate, it is being made the subject of critical examination by as precise investigation as possible of the relation between the quantity of carbon dioxide absorbed by photosynthesizing organisms and the nature and quantity of organic material formed therefrom. Detailed observations on sunflower leaves have tended to support the postulate, for a close quantitative equivalence between the carbon dioxide absorbed and the carbohydrates

formed has been obtained. It remains to be demonstrated whether the small deviation from exact equivalence is due to the diversion of a small fraction of the carbon dioxide to the synthesis of substances other than carbohydrates, or whether it is due to the subsequent rapid conversion of the photosynthesized carbohydrates into other products. The sunflower plant which was used as experimental material for these tests is a very effective carbohydrate synthesizer. It remains to be determined whether in other plants, particularly in those of a lower evolutionary level, the photosynthetic process follows the same course.

The structural elements of higher plants are composed primarily of cellulose and varying amounts of polyuronides such as hemicelluloses, pectin, and gums. The polyuronides are extremely complex compounds composed of five- and six-carbon-atom sugars combined with uronic acids in various ways. Virtually nothing is known concerning the mode of formation of polyuronides, of the role they play in the economy of the plant, or of their dietetic value, although they constitute a very considerable part of the farm and forest crops. Within recent years compounds containing uronic acid units have gained added interest because of their significance for certain aspects of detoxication and immunology in the animal organism.

The idea has been advanced that the polyuronides are formed from starch, which of course is widely distributed in plants, through the oxidation of a part of the starch molecule. Efforts have been made to carry out such a reaction in vitro with a view to accomplishing the transformation of the starch molecule into a uronic acid. Uronic acids are characterized by the fact that when heated with 12 per cent hydrochloric acid they yield about 25 per cent of carbon dioxide. They can also

be identified by means of a very characteristic color reaction with naphthoresorcinol. By oxidation of starch, under carefully controlled conditions, with hydrogen peroxide in the presence of a small amount of an iron salt, an interesting product was obtained which lost carbon dioxide with great ease in amounts corresponding to those yielded by a uronic acid, but which proved not to be of this category of compound. Evidence was obtained that the starch molecule, in the course of its oxidation with hydrogen peroxide, splits into units of more than six carbon atoms, forming the same product which is obtained from maltose by the same oxidizing agent.

In furtherance of the objective of experimental taxonomy to extend knowledge regarding the processes of evolution in flowering plants, several kinds of experiment are in progress. During the past year studies on the nature of climatic races have been emphasized, because these are apparently among the most important steps in the building up of larger evolutionary units. For these studies naturally growing populations of the yarrow, *Achillea*, and of *Potentilla*, a close relation of the strawberry, have been investigated. These have been brought from diverse environments into cultivation under similar conditions. Observations on these, and genetic experiments on the Madiinae, are revealing the structure and relationships of climatic races. For such studies a much more intensive sampling of populations is necessary than was used in the previously completed transplant experiments. Such procedure makes possible a more adequate appraisal of the continuities or discontinuities that exist among climatic races.

In central California, populations of *Achillea* occur from the coastal bluffs at the Pacific to near the crest of the Sierra Nevada at 11,000 feet elevation, and east-

ward across the Great Basin and northward to Alaska. Two species meet on the lower western flank of the Sierra Nevada. These are marked by a difference in chromosome number that is an effective barrier to interbreeding. Yet the differences in form between the races within each species are very much greater than those between the contiguous races of the two species.

The climatic races of *Achillea* differ by many characters affecting both the form of the plants and their response to the environment. The distribution of the races closely parallels the major climatic belts found in a transect across California, as identified by the life zones. There are many colonies of each climatic race. Samples of colonies of *Achillea* taken at frequent intervals across California show that as one moves inland from the coast some miles, the dominating influence is roughly the distance from the sea. Farther inland, as in the Sierra Nevada, the dominating influence becomes altitude. Though each colony shows a marked diversity of heritable variation, as a whole it reflects the kind of habitat to which it is native.

It is too early to state whether the variation observed within and between climatic races is essentially continuous or discontinuous, but almost all the colonies under study contain a small percentage of individuals with characteristics of the adjoining climatic races. This observation frequently applies to such characters as time of flowering and winter dormancy, and may extend to other physiological characters. This suggests the possibility that within natural colonies new forms may originate through genic recombination and natural selection.

No precise information is at hand concerning the nature of the physiological differences that mark climatic races. This important gap in the information needed

for a clear understanding of evolutionary processes has been realized for some time. The intensive sampling and study of colonies of *Achillea* and *Potentilla* is giving essential information and materials for experiments in comparative physiology. In these experiments it is planned to compare the effects of one environmental variable on several basic physiological functions under controlled conditions, using plants of very different climatic races.

An apparatus for quantitative physiological experiments of this type has been designed and partly constructed. Radiation, temperature, and relative humidity can be regulated within broad limits. This equipment is to be used in the study of photosynthesis, respiration, and absorption of water by roots. Another apparatus, designed for exploratory experiments on the effect of different soil temperatures on growth of different climatic races, has been constructed and put into operation.

During past years considerable attention has been given to field investigations of the influence of environment on plants. Several of these projects have recently been brought to completion. The functioning of living organisms under the extremely severe environmental conditions of the desert presents an extraordinarily complex picture. The results of investigations in this field are now also being assembled for publication. It was essential, first of all, to obtain a picture of the vegetation of the arid regions on the background of the complex of environmental conditions of which the vegetation is a product. This has been done by means of extensive exploration and study of the composition, relationships, and distribution of the desert vegetation. In these investigations the study of the plant and of the environment have gone hand in hand.

The impression given by a desert landscape is largely made by its plants. Their

wide spacing, low stature, and many highly specialized forms create plant communities of distinctive aspect. Plants living near the limits of existence are more sensitive than others to small differences in environmental conditions. From this responsiveness follows the great variety of plant communities that distinguishes the different parts of the desert. In the field work of the past ten years it has been possible to examine at least a very high percentage of the communities found in the central and southern parts of the North American Desert. The physiognomy, structure, and composition of the communities have been determined. An understanding of the dependence of each community on a particular group of climatic and soil conditions has been approximated, but its precise determination in each case would require investigation far beyond the limits of the current projects.

The exploration of desert areas in Texas and on the Mexican plateau during the past four years has modified some of the conceptions based on earlier work in Arizona and Sonora. Particularly it has revealed a wider range of climatic conditions under which desert vegetation is found.

Low rainfall is the basis of desert, but it is neither a simple nor an isolated factor in relation to plants. Over much of the southwestern United States there is a close correlation between rainfall and vegetation, but in northern Mexico the correlation is highly modified. A study of available rainfall data for the entire North American Desert and the adjacent regions has been found necessary to an understanding of local conditions in any part of this area.

The forces of the environmental complex are constantly changing in relative intensity and effectiveness. Many of these environmental and climatic influences are clearly discernible in the form and dis-

tribution of living organisms. The world today represents the resultant of past and present forces. The past has significance in so far as it enables us to understand the present and in a measure to predict the future.

Plants of later geologic time provide one of the best means for reconstructing the topography and climate of the past. They are closely related to modern plants, whose environmental requirements may be readily determined and projected back into ages before man lived upon the earth. Many Tertiary forests were made up of elements which now live under varied conditions in widely separated parts of the world. In his search into the record of earth history, the paleobotanist must fit together the evidence of such forests, and draw a picture of yesterday colored by his knowledge of today.

Many millions of years ago the vegetation of Oregon included a mixture of such conifers as swamp cypress and redwood, trees now living on opposite sides of the continent. Mingled with them were black oaks and hickories like those growing in the cypress swamps of Indiana, together with tan oaks and maples whose modern descendants live with the redwood in California. The disappearance of these trees from Oregon during the long years since the Miocene has been largely the result of climatic changes associated with the uplift of the Cascade Range. Their survival in Indiana and California has been made possible by the continuance there of living conditions like those of the past. There is reason to believe that earth changes may further alter the distribution of forests, that the planet on which we live has not reached the end of its dynamic course, and that man as well as plants will continue to be modified by the trend of its future history.



Dr. Emmett Martin has been called to special scientific work in connection with the war; Malcolm Nobs, assistant in taxon-

omy, has joined the Army; and R. F. Lucy, who has served as part-time artist, has joined the Coast Guard.

## BIOCHEMICAL INVESTIGATIONS

H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN, W. M. MANNING, H. W. MILNER, AND G. J. HARDIN

### PIGMENTS OF DIATOMS AND ALGAE

*Diatom pigments.* Considerable previous work had failed to give a clear understanding of the green and yellow pigments contained in diatoms. It was generally recognized that chlorophyll *a* was the principal green pigment (as in higher plants), that fucoxanthin was the principal xanthophyll, and that beta-carotene was the principal carotene. It was uncertain whether another green pigment observed in extracts of diatoms was chlorophyll *b* (the second green pigment of higher plants) or chlorofucine (a chlorophyll-like pigment first observed in brown algae and often reported to be a post mortem product). The nature of the diatom xanthophylls other than fucoxanthin and their relation to the common leaf xanthophylls was not known.

Analysis by Drs. Strain and Manning of diatoms (*Nitzschia closterium* grown in pure culture) has revealed that chlorofucine as well as chlorophyll *a* occurs in the diatom extracts. When the cells were killed under various conditions and extracted with methanol, the same proportions of chlorofucine and chlorophyll *a* were always obtained. Chlorofucine is, therefore, to be regarded as a normal constituent of the diatoms and not as a post mortem product.

Chlorofucine absorbs relatively very much less light in the red region of the spectrum than in the blue. Comparison of its spectral absorption curve with that of chlorophyll *a* revealed that, for methanol extracts of diatoms in the spectral region

between 455 and 490 m $\mu$ , chlorofucine absorbs considerably more light than chlorophyll *a*. This indicates that chlorofucine may play an important role in the photosynthetic activity of diatoms.

Especially sensitive adsorption methods for the detection of chlorophyll *b* in plant extracts were developed and applied to extracts of diatoms. No trace of this pigment was observed.

In conformity with earlier investigations, fucoxanthin was found to be the principal xanthophyll in the diatom extracts. In addition, however, this pigment was found to exist in at least three forms that are readily interconvertible by heat or by traces of iodine. Extraction of the cells under mild conditions always gave the same mixture of these three fucoxanthins. Unless a rapid interconversion takes place immediately upon death of the cells, all three fucoxanthins probably represent normal constituents of the diatoms.

The principal, most stable fucoxanthin represents about 90 per cent of the equilibrium mixture. It is adsorbed below the other two on columns of sugar. It shows a single definite spectral absorption maximum (452 m $\mu$  in ethanol). Each of the other two isomers shows a spectral absorption maximum about 6 to 7 m $\mu$  nearer the violet region of the spectrum. By analogy with other carotenoid and polyene compounds, these interconvertible fucoxanthins probably differ in the spatial arrangements about double bonds in the molecules.

Earlier work by Dr. Strain had shown

that the xanthophylls of higher plants can also be converted into isomeric pigments, but only the most stable isomers had been observed in leaves. The occurrence of several labile fucoxanthin pigments in diatoms, coupled with the fact that fucoxanthin appears to play a role in photosynthesis, suggests that this isomerization may be associated in some way with the function of the pigment in the photosynthetic reactions.

In addition to the three isomeric fucoxanthins, diatoms contain appreciable quantities of several other xanthophylls. One of these is weakly adsorbed and passes rapidly through the adsorption columns. Its spectral absorption curve is similar to that of zeaxanthin, but the absorption maxima are at slightly shorter wave lengths. Another xanthophyll present in somewhat larger quantities is remarkably similar to lutein, the principal xanthophyll of higher plants. This pigment and lutein show so nearly identical spectral absorption curves that they can easily be confused. They can be differentiated with certainty only by the slightly greater chromatographic adsorbability of the diatom pigment. Not one of the common leaf xanthophylls was detected in diatoms.

There is a marked difference between the spectral absorption curves of the fucoxanthins and those of the other xanthophylls and the carotene found in diatoms. For example, at a wave length of about 540 m $\mu$  fucoxanthins absorb considerable light, whereas the carotene and the other xanthophylls absorb virtually none. This fact has been made use of, in conjunction with the spectral curves of the several pigments, to calculate the amount of light absorbed by the different groups of pigments in the diatom extracts. At all wave lengths in the visible spectrum, chlorophyll *a*, chlorofucine, and the fucoxanthins together absorb 70 per cent or more of the

total amount of light absorbed by all the pigments in the methanol extracts. Whether or not these same relations hold in other solvents and in the leaf might be investigated with profit.

The photosynthetic apparatus of the diatoms has been varied by culture of the organisms in light of different spectral properties. Diatoms grown in "neon" light show a large increase in the lutein-like xanthophyll as compared with organisms grown in white light. When diatoms are transferred from white to "neon" light, this change takes place slowly and becomes substantial only after several generations of diatoms have been grown under the new light conditions. These observations point the way to two important fields of biological investigation. They indicate that products of probable functional importance may be varied a great deal in response to changes in external or environmental conditions. By careful control of external conditions it may become possible to vary at will the chemical products of Nature's greatest factory, the green parts of plants. Because changes of this nature may be involved in the early stages of the development or evolution of plant varieties, further studies of the physiological response of unicellular, autotrophic organisms to their environment may yield new methods and fresh views pertaining to the development of plant types.

*Pigments of brown algae.* Reports of the occurrence of both chlorofucine and fucoxanthin in brown algae prompted an examination of the pigments of several representatives of this group of plants. All the ten species examined contained chlorophyll *a* and chlorofucine. Chlorophyll *b* was not detected. All these species contained mixtures of the three fucoxanthins and all contained beta-carotene. Although lutein had been reported previously as a constituent of the brown algae, all the species ex-

aminated contained instead several other xanthophyll pigments with spectral absorption properties similar to those of xanthophylls found in green leaves. One of these pigments resembled flavoxanthin; two of them were similar to violaxanthin. One of these violaxanthin-like pigments is very difficult to separate from the flavoxanthin-like pigment; the other is adsorbed near the principal fucoxanthin on the adsorption column. The lutein-like xanthophyll found in diatoms was not observed in appreciable quantities in the brown algae.

Like the diatoms, the brown algae are widely distributed and of great quantitative importance over large areas. This lends further support to the view that both chlorofucine and fucoxanthin may be important pigments in the carbon economy of nature.

*A new chlorophyll from red algae.* Further clues to the natural variability of the photosynthetic apparatus have been obtained from a cursory examination of the pigments of red algae. None of the species examined, representing some six or eight genera, contained either chlorophyll *b* or chlorofucine. In addition to chlorophyll *a* they yielded smaller quantities of another green pigment, a hitherto undescribed chlorophyll. This new chlorophyll shows maximum absorption far in the red and violet regions of the spectrum (maxima at 696, 456, and 401 m $\mu$  in methanol). Because the absorption maximum in red light is so far removed from that of chlorophyll *a* (665 m $\mu$  in methanol), the new chlorophyll is readily detectable by spectroscopic examination of methanol extracts of the algae. Relatively to the chlorophyll *a*, the quantity of the new chlorophyll varies a great deal in different species. The largest amounts have been found in two species of *Gigartina* (*Agardhii* and *papillata*) and in *Erythrophyllum*.

On adsorption columns of sugar, the

new algal chlorophyll is adsorbed not far above chlorophyll *a* and just below where chlorophyll *b* would occur. In the light of our experience with adsorption columns, this behavior suggests that the new pigment is probably closely related to chlorophylls *a* and *b*. When treated with acid this chlorophyll is converted into a gray pigment, pheophytin, that is very similar to or identical with the pheophytin obtained from chlorophyll *a*. This indicates a close relationship between chlorophyll *a* and the new algal chlorophyll.

In white light, solutions of the new chlorophyll are weakly fluorescent, but this apparent weakness of the fluorescent light may be due to the insensitiveness of the eye to light of such great wave length. In ultraviolet light, solutions of the new chlorophyll are bright red.

In view of the fact that the red-algal chlorophyll absorbs light in the far red region of the spectrum, where other pigments do not absorb appreciably, it should be possible by quantum-yield measurements to determine with certainty whether or not light absorbed by this chlorophyll is utilized in photosynthesis.

*Implications.* For many years it has been generally thought that the chlorophyll pigments in plants are subject to little or no variation. These investigations of diatoms, brown algae, and red algae indicate that the chlorophylls and also the yellow pigments in different algal classes are much more variable than was previously supposed.

These results justify the belief that the photosynthetic mechanism is not necessarily identical in all groups of plants. Theories concerning the mechanism of photosynthesis, and of energy transfer between pigments, should be re-examined in the light of these possible variations. Further investigations of the photosynthetic process in various algae are certainly to be desired.

The results of these pigment studies thus far also justify the belief that investigations of this type may provide an additional key to phylogenetic relations between the various algae. Taxonomists are able to place practically all known algae in a few well defined classes, but they are not able so easily to tell the probable relations between the various classes. Pigments related to the photosynthetic mechanism are of basic importance to the plant and must reflect some of the most important characteristics of its genetic makeup. It is reasonable to suppose that, in general, two groups of plants having several pigments in common are more closely related than groups having fewer pigments in common. Without considering other lines of evidence, at least two tentative conclusions can be drawn from this work thus far. One is that the green algae are less closely related to the groups of algae which have been investigated than they are to the higher plants. The other is that diatoms are probably more closely related to the brown algae than either group is to red algae or to green algae. These conclusions are based on the observations that (1) chlorophyll *a* and beta-carotene are probably the only pigments occurring in green algae and higher plants which also occur in perceptible amounts in diatoms and brown algae; (2) diatoms and brown algae have in common (in addition to chlorophyll *a* and beta-carotene) chlorofucine and the various fucoxanthin isomers; (3) red algae contain neither chlorofucine nor chlorophyll *b* but do contain another chlorophyll not found in diatoms and brown algae.

Obviously a detailed study of the green and yellow pigments in other groups of algae should yield many more clues regarding genetic relationships.

#### BIOCHEMICAL AND PHYSIOLOGICAL STUDY OF DIATOMS

To aid in the study of the chemistry and physiology of diatoms, it was found desirable to produce in pure culture relatively large quantities of diatoms (several grams at least). A gram of diatoms does not sound like a very large quantity until one undertakes to grow that amount in pure culture. In round numbers a gram (dry weight) of the marine diatom *Nitzschia closterium*, as commonly cultured, represents a hundred billion diatoms in 10 liters of sea water. Drs. Manning and Hardin have undertaken the isolation and culture of a number of different species of diatoms and other algae to be used in these investigations.

*Culture methods.* A glass culture vessel of 10-liter capacity has been assembled and put in operation for growing *Nitzschia closterium*, with provisions for maintaining the culture pure (i.e., uncontaminated with bacteria or other organisms). Air is supplied to the culture vessel by means of an aquarium pump, the air being filtered through sterile cotton before being admitted to the culture. Light is furnished by a spiral consisting of approximately 36 feet of "snow white" fluorescent tubing, which surrounds the vessel and furnishes an illumination approximately equivalent to one-eighth of full sunlight. Light of such intensity unfortunately brings with it considerable heat even from the relatively cool fluorescent light source. This heat, if not removed, would soon kill the diatoms in the culture. To conduct the heat away as rapidly as possible, chilled water is circulated through a cooler, constructed from two large concentric glass cylinders, which is inserted into the culture vessel. Additional light is provided by several turns of fluorescent tubing inserted in the inner cylinder. Provision is

made for drawing off portions of the culture from time to time and adding fresh sterile culture solution without introducing contamination. By this procedure it is possible to maintain the culture in approximately constant physiological condition and to obtain fairly large quantities of material at regular and frequent intervals. The procedure is very satisfactory for maintaining cultures of *Nitzschia closterium* except that the temperature problem is made somewhat difficult by the relatively low heat tolerance of this diatom. If the temperature of the culture rises much above 19° C. the multiplication rate is seriously reduced.

To supplement the studies with *Nitzschia*, and with the hope that perhaps some fresh-water diatom will have a greater tolerance for high temperatures and be equally satisfactory in other respects, the possibility of substituting a fresh-water form for the marine one is now being investigated. To date six species of fresh-water diatoms have been obtained in pure culture. Before mass culturing of these species is attempted it will be necessary to determine the best available conditions for their culture, and such studies are now under way. Besides giving a larger field from which to select forms most amenable to laboratory study, the obtaining and study of many different species of diatoms has the advantage of rendering more secure any generalizations that may be made about the metabolism of diatoms.

For purposes of comparison, it is also planned to culture unicellular algae other than diatoms. Sufficient equipment has been assembled for the simultaneous operation of three large culture vessels. One of the light sources consists of neon-filled tubing instead of fluorescent tubing.

In the preliminary culturing of diatoms one curious observation has been made

which merits mention and further study. It is generally true that a pure culture of an alga will grow in the presence of glucose and usually will grow much more luxuriantly than in a simple mineral medium where it must synthesize its own organic matter. It has been found, however, that the growth of the diatom *Nitzschia closterium* is completely stopped in rather low concentrations of glucose (0.1 per cent). This observation certainly bears on the supposed course of photosynthesis. One would expect any substance in the direct line of photosynthetic products to be utilized by the organism. If this is a valid assumption, it would appear improbable that glucose is involved in the photosynthetic process of the one diatom species tested to date. Obviously more work bearing on this point needs to be done.

*Measurement of photosynthesis.* An apparatus has been assembled for measuring photosynthesis in diatoms or other plankton algae under conditions which should permit the algae to continue normal growth during fairly extended periods of measurement. Another feature of the apparatus is provision for measuring rates both of carbon dioxide uptake and of oxygen evolution. The ratio of these rates gives an indication of the types of product being formed by a plant during a period of photosynthesis. The 2-liter reaction vessel which is employed for the photosynthetic measurements accommodates a volume of algal suspension large enough to permit direct chemical analysis of the material which has undergone a period of measured photosynthesis. The combination of chemical analysis and detailed photosynthetic measurements on the same material should provide information not otherwise obtainable regarding the photosynthetic and other metabolic products of diatoms.

### THE NATURE OF THE PHOTOSYNTHATE IN SUNFLOWER LEAVES

For many years it has been known that carbohydrates make up a considerable portion of the organic matter produced by photosynthesis in higher plants. How nearly carbohydrates constitute all the organic matter thus produced has been tested in only a few cases. In these cases the amount of carbohydrate material recovered fell far short of the quantity anticipated from the amount of carbon dioxide absorbed.

Dr. Smith, assisted by Dr. S. S. Todd and Mr. D. Frazier, has undertaken an accurate investigation of the nature and amount of the organic matter formed during the illumination of sunflower leaves in relation to the amount of carbon dioxide absorbed. Indirect evidence of the nature of the photosynthate (the organic matter formed during photosynthesis) was obtained from a determination of the increase in dry weight produced in a leaf by the assimilation of a known quantity of carbon dioxide. For this purpose the two halves of a leaf, separated from the midrib, were used. One half was placed in an atmosphere containing carbon dioxide and illuminated, and the amount of carbon dioxide that it absorbed measured. The other half was kept in the dark and served as a control. From dry-weight determinations on the two portions of the leaf, the increase in dry weight of the illuminated portion was obtained. The procedure made it certain that the transfer of material to and from the leaf could take place only through the atmosphere surrounding the leaf. That this was true was demonstrated by combustion analyses; which showed that the increase in the carbon content of the illuminated leaf was equal to the decrease in carbon content of the atmosphere surrounding the leaf.

Several determinations of the ratio of the increase in carbon content of the illuminated leaf to the increase in dry weight yielded a value for the percentage of carbon in the photosynthate of  $41.38 \pm 0.60$  per cent. This value clearly approximates the percentage of carbon in a disaccharide (cane sugar, for example, contains 42.10 per cent carbon) and suggests that the photosynthate may be carbohydrate alone. However, the carbon content of the dried sunflower leaves used as controls for the photosynthesis experiments was  $45.74 \pm 0.24$  per cent. On an ash-free basis this corresponds to a carbon content of 51 or 52 per cent for the organic material of the leaf. This value is considerably higher than the carbon content of the photosynthate, or even of cellulose (44.4 per cent), and indicates that subsequent metabolic processes of the leaf may transform the organic matter formed during the photosynthesis into a more highly reduced state.

Direct analysis has shown that the organic matter formed by the sunflower leaf during a short period of illumination (about 60 minutes) consists largely of carbohydrates,  $91.87 \pm 1.46$  per cent. By suitable analytical procedures these carbohydrates can be separated into several fractions. The percentage of the assimilated carbon attributable to each of these fractions is as follows:

Fraction	Percentage
Glucose + levulose .....	9.98
Sucrose .....	51.92
Unidentified sugar .....	3.12
Unidentified polysaccharide ..	1.38
Starch .....	25.49

In these experiments the leaves, after removal of the midrib, were quartered and alternate quarters used as control and as photosynthesizing agent. Quartering rather than halving insured a greater similarity

of the two leaf portions. Removal of the midrib avoided the loss of organic material by transport but deprived the leaf of external water supply, with consequent water deficit. This may have altered the normal ratios of the carbohydrates to one another.

The residue from the illuminated portion of the leaf, after removal of all soluble material, contained a portion of the photosynthate. It is not known whether this part of the photosynthate consisted of carbohydrate (cellulose, hemicellulose, etc.) or of protein, but nitrogen analyses indicated that possibly a part of it might be protein. At the present stage of the investigation, values for the carbon content of this portion of the photosynthate must be assumed. Calculations based on the percentage of carbon in cellulose and in protein would assign to this portion of the photosynthate 6.49 and 7.61 per cent, respectively, of the total increase in content of carbon. The total recovery of carbon would be then either 98.36 or 99.48 per cent, with a probable error of about  $\pm 3$  per cent.

In the experiments just described, the leaves photosynthesized for about an hour and respired for an additional 20 minutes before being killed. During this time respiration and other nonphotosynthetic transformations of carbohydrates undoubtedly occurred. These transformations may have caused the recovery of carbohydrate to be less than the amount actually formed by photosynthesis, and an attempt was made to determine whether or not this was so. For this purpose the percentage recovery of assimilated carbon in the form of carbohydrates was determined after a 4-hour dark period immediately following a period of photosynthesis. In some instances, during the prolonged respiration, a much greater loss of carbohydrates took place than was attributable to respiration as measured by carbon dioxide liberation.

This suggests that a rapid synthesis of other substances takes place from carbohydrates and accounts in certain experiments for the exceedingly low recovery in the form of carbohydrates. In other cases the liberation of carbon dioxide from the leaf exceeded the loss of carbohydrates, and a recovery of an apparent excess of carbohydrates resulted. Whether part of this excess arose from an additional synthesis of sugar in the dark is not known. The results of these experiments were too inconsistent to justify generalization, but they were sufficiently clear to explain the variations in the recovery values of carbohydrates. The factors influencing these changes are still beyond our knowledge.

The results of these experiments show that the preponderant products of the photosynthetic activity of sunflower leaves are carbohydrates, and that if other substances are formed they constitute only a small part of the photosynthate.

Although these experiments demonstrate that photosynthesis by sunflower leaves may produce a quantity of carbohydrate equivalent to the quantity of carbon dioxide absorbed, the carbohydrates formed may or may not incorporate the same carbon atoms as are absorbed. It is conceivable that the assimilation of carbon dioxide may initiate a chain of reactions which culminates in a quantitative yield of carbohydrates without incorporating into these carbohydrates the particular carbon atoms absorbed. The present experimental methods are ill suited to distinguish between these two possibilities, direct and indirect formation of carbohydrates, but by the use of labeled carbon such a distinction should be possible.

Because of war conditions this tracer element has not been available. It may be feasible to prepare radioactive carbon,  $C^{14}$ , by means of the Stanford cyclotron, and experiments are now under way, in which

the Department of Physics of Stanford University is generously cooperating, for the purpose of examining this possibility.

#### PLANT POLYURONIDES

Although polyuronides such as hemicelluloses, gums, mucilages, and pectin are widespread and constitute a very appreciable part of the framework of higher plants, virtually nothing is known regarding the mode of formation of these substances. There has been some indication that they may be derived from starch through a series of steps involving the oxidation of the primary alcohol groups with the formation of uronic acid units. An effort has been made by Dr. Spoehr and Mr. Milner to determine whether the primary alcohol groups of starch can be oxidized *in vitro* to form substances containing uronic acids.

The most promising oxidizing agent was found to be hydrogen peroxide in the presence of a small amount of ferrous sulfate. With this reagent the starch was readily oxidized at 20° C. and was simultaneously hydrolyzed. By treatment with boiling 12 per cent hydrochloric acid polyuronides are decarboxylated and yield 25 per cent of carbon dioxide and appreciable amounts of furfuraldehyde. In a series of oxidations of starch, using 1 to 8 mols of hydrogen peroxide per glucose unit, the oxidation product giving the highest yield of carbon dioxide by the method just mentioned was obtained with about 5 mols of hydrogen peroxide. This yield of carbon dioxide amounted to 22.56 to 25.20 per cent in various preparations. This oxidation product proved, however, not to be a uronic acid, as it did not give the characteristic reaction with naphthoresorcinol, and yielded but small quantities of furfuraldehyde. As by-products in this oxidation, carbon dioxide, formic acid, and oxalic acid are also formed, increasing in

quantity with the use of larger amounts of the oxidizing agent.

The oxidation product obtained with 5 mols of hydrogen peroxide is very soluble in water, methanol, and ethanol, and insoluble in ether, acetone, and nonpolar solvents. Unfortunately it could not be crystallized. Neither could well defined metal or alkaloid salts be obtained, nor definite compounds with phenylhydrazine, its substituted derivatives, or other organic compounds. This is apparently due to the fact that the oxidation product is very easily decarboxylated. In water solution it loses carbon dioxide slowly at room temperature, loses it more rapidly at 50° C., and at 100° yields about 18 per cent; this is to be compared with a yield of 24 per cent carbon dioxide by treatment with 12 per cent hydrochloric acid. A water solution of the oxidation product when treated with brucine, strychnine, pyridine, phenylhydrazine, aniline, o-phenylenediamine, or o-toluidine rapidly liberated 3 to 5 per cent carbon dioxide.

When exposed to light in the presence of air, a water solution of the oxidation product yields large amounts of carbon dioxide. At 20° C. about 75 per cent of the substance is thus oxidized to carbon dioxide in 32 hours, the photooxidation proceeding approximately linearly with time. The oxidation product has strong reducing properties; it reduces silver nitrate in the cold, also potassium permanganate, iodine, Benedict solution, and sodium 2,6-dichlorobenzenoneindophenol. It showed no vitamin C properties when tested on guinea pigs.

A molecular weight of 306 was obtained by the cryoscopic method in water solution, and although the electrometric titration curve was of indefinite shape, an equivalent weight of 140-150 was obtained, indicating a dicarboxylic acid. In view of the fact that it loses 2 mols of carbon dioxide



when treated with 12 per cent hydrochloric acid and that at least half of this carbon dioxide is lost with great ease, the substance is probably in part a  $\beta$ -keto acid. Combustion analysis gave results agreeing well with the empirical formula  $C_{10}H_{12}O_{12}$ .

Both glucose and maltose were oxidized with the same oxidizing agent. With 3 mols of hydrogen peroxide, in comparison with starch, glucose yielded about 8 times as much formic acid, very little oxalic acid, and a main oxidation product which yielded only 10 per cent of carbon dioxide when treated with 12 per cent hydrochloric acid. Maltose, on the other hand, when oxidized with 8.4 mols of hydrogen peroxide (equivalent to 4.2 mols per glucose unit), yielded, besides small amounts of formic and oxalic acids, a main oxidation product having the same properties and yielding the same percentage of carbon dioxide on decarboxylation as the product obtained from starch. The molecular weight of the oxidation product obtained from maltose was also very nearly the same as the value obtained for the starch oxidation product, and the combus-

tion analyses of the two substances were in close agreement.

These findings may prove to have some bearing on the constitution of the starch molecule, a problem which has occupied chemists for many years. The enzymatic hydrolysis of starch yields maltose, whereas hydrolysis with acids usually yields glucose. When starch is treated with hydrogen peroxide in the presence of small amounts of iron, the main product formed represents a molecule which is larger than could arise from the oxidation of glucose. This indicates that with this reagent the starch in the course of oxidation splits into units of more than six carbon atoms. Although it is impossible to determine at what stage of the oxidation splitting of the starch molecule occurs, the fact that the same product is obtained from starch and maltose indicates that the oxidation product of starch is derived from a maltose unit. Evidence obtained thus far does not warrant assigning a structural formula to the oxidation product obtained from starch, although several  $C_{10}H_{12}O_{12}$  formulas can be written which are consistent with the observed properties.

## EXPERIMENTAL TAXONOMY

JENS CLAUSEN, DAVID D. KECK, WILLIAM M. HIESEY, AND E. V. MARTIN

Fundamental to our understanding of plant relationships is knowledge concerning the make-up of climatic races of the same or of closely related wild species. In climatic races we can study evolutionary divergence in its early stages, and then progress to differences of greater order such as are found in species and genera. An understanding of the principles that govern the distribution of such races is basic not only to an understanding of evolution, but also to successful plant breeding, because cultivated plants, like wild ones, are healthier and more productive

when they fit the environment in which they are grown. During the past year considerable progress has been made in the study of genetic variations of natural populations of *Achillea* and *Potentilla glandulosa*.

The general organization of plant groups into recognizable units of successively higher order as disclosed by experimental means has already been outlined (Year Book No. 39, pp. 158-163, and No. 40, pp. 160-170). Such categories include local populations, climatic races, species, species complexes, and genera. The relations be-

tween the higher categories have been most effectively studied in the annual species of the Madiinae and will be the subject of publications now in preparation. For the study of the lower categories, such as the climatic races or ecotypes within one species, perennials such as *Achillea* and *Potentilla* are more suitable because their species range over several climatic zones and have evolved a much richer array of races. From the appearance of plants in the wild, one would conclude that *Achillea* has evolved series of continuously intergrading races in certain areas.

#### HEREDITARY COMPOSITION OF CLIMATIC RACES

Basic to the whole idea of evolution by natural selection is individual variability. Modern genetics has been built upon the study of the inheritance of individual differences so distinct that they can be readily separated and classified—the so-called mutants. The neo-Darwinian theories of natural selection are based mainly on facts known about such characters. Although the mutants analyzed in laboratory experiments are indispensable for the study of the laws governing inheritance in general, their survival value in natural selection is very questionable. Therefore, before results from laboratory experiments can be utilized in explaining evolution, they need to be corroborated by studies on characters typical of wild plants.

After extensive studies on the cytogenetics of wild populations, it appears that the theories of evolution by mutation and recombination have generally been oversimplified. This becomes evident when contrasting climatic races of a species are crossed, and the hybrid segregants of the second and third generation are studied. Climatic races differ by many characters, and the segregations indicate that even small morphological differences are deter-

mined not by one, but by several pairs of genes, each changing the individual slightly. The effect of the individual gene in wild races is therefore less upsetting to existing gene balances, but also less distinct in expression, than that of genes utilized in orthodox genetic experiments.

The number of genes determining each character is limited, however. It has been found, for example, that differences in habit, mode of branching, earliness of flowering, color of flowers, shape of seeds, and other characters found between climatic races are frequently governed by no more than three or four pairs of genes. In some races the genes for different characters may show linkage, in others not. The important fact is that the inheritance of these characters is neither very simple nor so complex that small but discontinuous steps of evolution, such as are postulated by classic genetic theory, are ruled out.

Seedlings of wild populations of both *Achillea* and *Potentilla glandulosa* from many points in the Coast Ranges and from approximately 1000-foot altitudinal intervals along our Sierra Nevada station transect are being grown at Stanford for careful comparative study. Seedling cultures of *Achillea* attain maturity within two years, but the *Potentillas* require an extra year for their full development and the first of them are just now beginning to manifest their characteristic differences in the Stanford garden.

As previously pointed out (Carnegie Inst. Wash. Pub. 520, pp. 296-300), the climatic races of *Achillea* in California belong to two species which apparently do not overlap, but together cover the entire transect from the coast to the desert plateaus. At latitude 38° north, *Achillea borealis*, with 27 pairs of chromosomes, covers the distance from the coast to the Sierran foothills, and the 18-chromosome

*A. lanulosa* extends from the lower borders of the Transition zone, at 3000 feet in the Sierra Nevada, to above tree line

Alaska, and *lanulosa* eastward to the Great Plains over a great altitudinal and climatic range.

# STEM-HEIGHT FREQUENCIES IN ACHILLEA RACES AT STANFORD

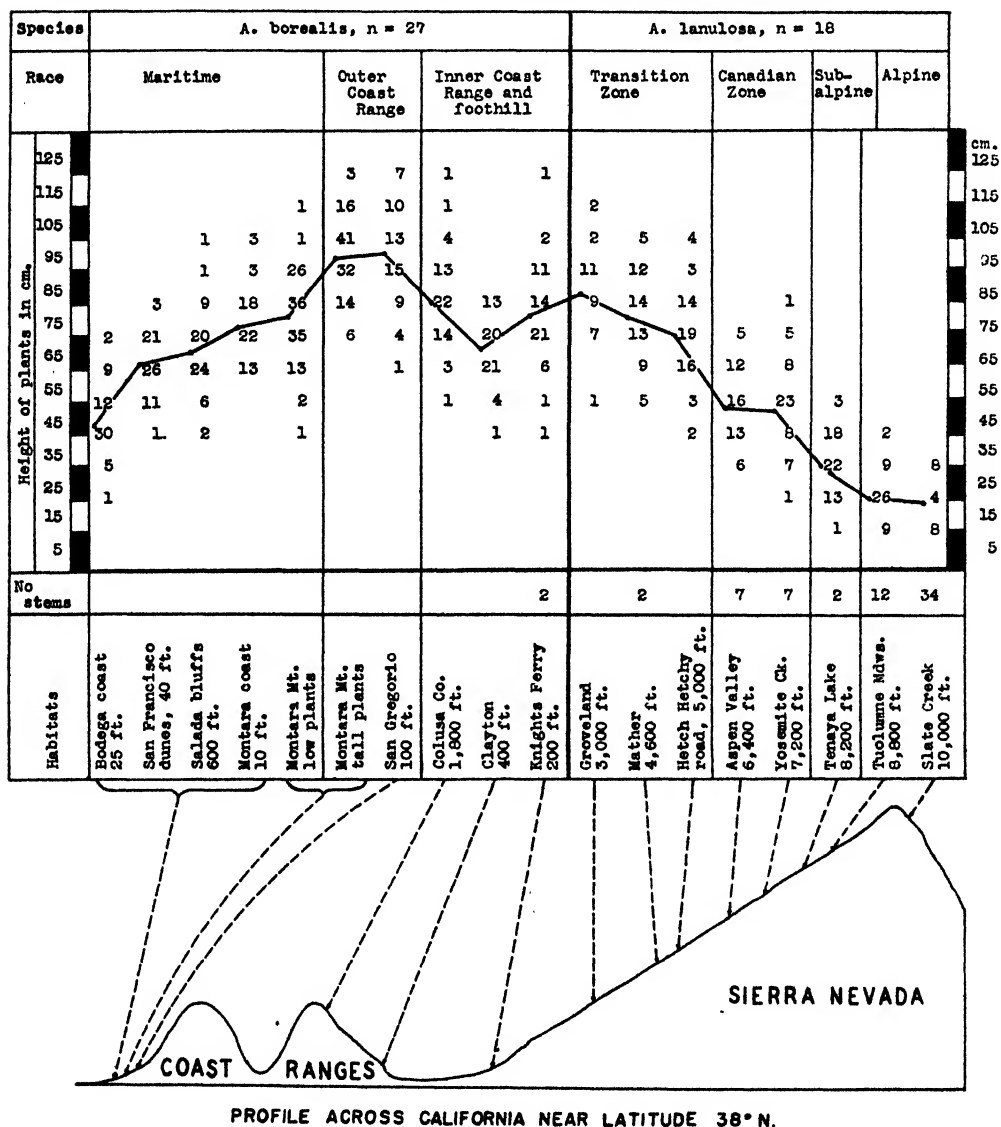


FIG. 1. An analysis of climatic races of *Achillea* assembled in a uniform garden. See text.

at 11,000 feet and down the eastern flank to the Great Basin. Both species contain contrasting climatic races. *Achillea borealis* extends northward along the coast to

An illustration of how characters in general may vary is given in figure 1, which shows the variation in height of flowering stems of eighteen populations of *Achillea*

from this transect. These were grown in a uniform garden at Stanford. The class frequencies for 10-centimeter intervals of plant height are given in the vertical columns, all but two of the populations consisting of approximately 60 individuals each. The curve passes through the mean height of each population, which is indicated by the scale at the sides of the graph. The geographical location from which the seeds for each population were taken is shown in relation to the profile of a transect across California below. The horizontal distances in the graph approximate functions of the topography of the cross section of California, starting at the Pacific to the left. The dominating influence in the left-hand part of the figure is the increasing distance from the sea, whereas in the right half the dominating influence is the increase in altitude of the habitats. The headings of the figure indicate the limits between the two species, and the climatic races represented. Although the sampling is more intensive than in the transplant experiments, each major race is represented by a minimum number of populations.

The extreme maritime race of *Achillea borealis* clings to the wind-swept, fog-laden, narrow strip of coast overlooking the ocean. Its genetically low habit is probably a selective response to the prevailing strong winds. The population from the Bodega coast north of San Francisco Bay is the most extreme of those illustrated, but an even more extreme form occurs 350 miles farther north on the bluffs near Port Orford, Oregon. The most maritime forms are low and spreading, with massive, thick-textured, dark-green rosette leaves, and late flowering such as is typical of maritime ecotypes of other species. In populations from somewhat less wind-exposed coasts, such as the dunes and bluffs of San Francisco and the coast at Montara,

the selection appears to have been less rigid. Although some individuals as extreme in appearance as those from the Bodega coast and Port Orford occur here, a slightly taller and earlier form is more common. This, however, has the characteristic maritime type of leaf.

As one moves inland from the windy coast, the maritime race is rapidly replaced by that of the outer Coast Ranges, a very tall but still fairly late-flowering form, which appears able to make maximum use of the abundant moisture in the coastal fog belt. The San Gregorio population in figure 1 is typical of this race. There is hardly any overlapping in height at Stanford between plants of this population and those from the most exposed coasts such as Bodega, but its smaller plants are a match for the taller ones from less exposed shores such as those of Montara and San Francisco. The leaves of the outer Coast Range race, however, generally have much less dense segments than those of the maritime race.

The maritime and outer Coast Range races meet a very short distance from the sea. The populations at these localities contain mixtures and recombinations of the two races. This is illustrated by the two populations from the base of Montara Mountain, a locality approximately  $\frac{1}{2}$  mile from the sea. One population was obtained by sowing seed gathered from plants of low stature only, and the other was derived from seed collected from tall individuals. When grown at Stanford, the two populations differed significantly in height, as can be seen in the figure. Moreover, the offspring from the short plants corresponded to the maritime race, whereas those from the tall ones resembled plants of the outer Coast Range race.

In the Upper Sonoran zone of limited rainfall around the valleys of the inner Coast Ranges and in the Sierran foothills

another recognizable race occurs. It flowers months earlier than the maritime forms, while there is still adequate moisture from early spring rains, and then dries up, becoming dormant during the summer and fall period. This is in contrast with the maritime race, which is ever-green when grown at Stanford, and also in contrast with the outer Coast Range race, which is intermediate between the maritime and foothill forms in earliness and dormancy. The three populations of the inner Coast Range and foothill race indicated in figure 1 are also distinguished from the maritime by their grayer pubescence and few rosette leaves. Each of these populations shows an appreciable amount of individual variability, the Colusa County population including individuals approaching those found in the outer Coast Ranges.

A giant form of *Achillea borealis* occurs in the Lower Sonoran zone in limited areas along streamways on the hot San Joaquin Valley floor. A population of this strain, which is early and in its native habitat reaches a height of 2 meters, has recently been acquired, but is too immature at this writing to be included in the tabulation.

In passing to elevations of 3000 feet in the Sierra Nevada, as at Groveland, where the ponderosa pine and incense cedar replace digger pine and blue oak, one encounters the Transition zone race of another species, the 18-chromosome *Achillea lanulosa*. Populations of this species up to 5000 feet closely resemble the foothill forms of *Achillea borealis*, although the cytological difference between them prevents free exchange of genes through crossing. Plants of the Transition zone race can be distinguished from the foothill race principally by chromosome number and by their much later flowering

when grown at Stanford. Also, they usually have smaller heads and more slender stems and remain green later in the summer.

All the climatic races of *Achillea borealis* indicated in figure 1, and also plants of the Transition zone race of *A. lanulosa* from lower elevations, remain green and active at Stanford during the winter. From higher elevations in the Transition zone upward, the plants show an increasing degree of winter dormancy and a lowering of stature at Stanford.

In populations from the Transition zone, a mixture of winter-green and winter-dormant plants is found, as well as individual variation in height. This has been observed, for example, in the Mather and Hetch Hetchy Road populations. At approximately 6000 feet altitude in the Canadian life zone, characterized by red fir and Jeffrey pine, the transformation from winter-green to winter-dormant plants is almost completed, and one encounters a climatic race that at Stanford attains a mean height approximately 25 centimeters less than that of the populations from the Transition zone. The Canadian zone race, exemplified by the Aspen Valley population, goes dormant during the winter at Stanford and is generally late and very erratic in its flowering. However, single plants comparable with those typical of the Transition zone are found mixed with the others, just as one finds mixed stands of Jeffrey and ponderosa pine. Near the upper edge of this zone there is considerable intermixing of this race with the subalpine race above it. For example, the variable Yosemite Creek population from 7200 feet includes plants indistinguishable in height, leaf form, pubescence, and time of flowering from Tenaya Lake plants of the subalpine race at an elevation of 8200 feet.

At around 8000 feet, in the lodgepole pine belt, the stems of *Achillea* are much shorter and more slender, and have more contracted inflorescences. Most conspicuously, the leaves are grayer-pubescent, much smaller, and proportionately much narrower. This trend continues to the upper limit of the species distribution at 11,000 feet. Parallel with these morphological differences is a lengthening of the dormancy period during the winter at Stanford, as compared with that of the plants of the Canadian zone. Taxonomically these subalpine and alpine forms are known as subspecies *alpicola*.

It appears that this high-montane subspecies is composed of more than one climatic race, a subalpine and an alpine. Figure 1 shows that there is a distinct difference in height and ability to flower at Stanford between the plants from Tenaya Lake, on the one hand, and those from Tuolumne Meadows and Slate Creek Valley on the other. This is also emphasized by differences in earliness of flowering, especially as observed on transplants at our alpine station in Slate Creek Valley. Both the subalpine and alpine races are erratic in their flowering at Stanford, an evidence of their being out of harmony with this environment. Some plants are extremely early, others very late, and more than 50 per cent of the plants of the most alpine population are unable to produce flowering stems at all. Also, the number of stems is very small in plants from high altitudes as compared with those from lower altitudes.

Each population from these higher altitudes contains a few individuals typical of the neighboring climatic race. A few characteristically alpine plants were found in the Tenaya Lake population, and a few of subalpine reaction from Tuolumne Meadows and Slate Creek Valley, but

more than 80 per cent of the individuals in each population were characteristic of the climatic race to which they were assigned.

At the uppermost limit of the range of *Achillea lanulosa*, 11,000 feet, the most dwarf, most pubescent, and apparently most uniform race of all is encountered, but transplants from this altitude are at the present writing too immature for study. The apparent uniformity of this extreme alpine recalls the relative homogeneity of the extreme maritime population of *A. borealis* from the Bodega coast, and suggests that at these extremes natural selection has been more rigid and the influx of genes from other racial elements more limited.

Finally, in the Great Basin, at 6000 to 8000 feet elevation, forms occur that are genetically taller than the alpine and among the most frost-resistant of all *Achilleas*. Plants of this race have been observed at the alpine station in early bloom and apparently undamaged after temperatures as low as  $-10^{\circ}\text{C}$ ., when other races were badly frozen. It is obvious that frost-hardiness is a desirable character for a plant native to the interior plateaus which have severe winter temperatures but very little snow cover. Cultures of this climatic race are still too immature to be included in the tabulations.

In summary, we find that the climatic races of *Achillea* reflect the changes in climate associated with the topography of California to a remarkable degree. Each major climatic belt has its climatic race of *Achillea*, of characteristic appearance and reaction. In gross features, the distribution of the climatic races appears to follow that of the characteristic trees and other indicator plants of the different life zones, although the agreement is not absolute.

No natural population of *Achillea* is uniform, but apparently each has sufficient variability and genes to provide for a considerable array of forms in any one environment. Some of this variability is evidently physiological. Judging from the reactions observed in the Stanford garden, this variability usually appears large enough to include a few individuals characteristic of the neighboring climatic races. Possibly more individual variability can be observed in the garden than in nature because of the elimination that takes place under natural competition. The variability demonstrated to occur in wild populations, however, suggests a range of physiological tolerance which, by genic recombination, may give rise to new populations successful in other habitats.

There is considerable evidence that forest trees and grasses have climatic races similar to those observed in *Achillea* and *Potentilla*. Several years' data have been gathered on the climatic races of the tufted hair grass, *Deschampsia caespitosa*. This species, like *Achillea*, occurs throughout the northern hemisphere. A few races from Scandinavia, from arctic Lapland, and from a transect across California from the coast to 10,000 feet altitude in the Sierra Nevada are being grown at the transplant stations. In this species the races native to the California mountains are constantly being exterminated by rust at Stanford, although they are not attacked in their native habitats. Though the other races succeed at this station, the loss of the mountain races here is a handicap in the investigations. These observations and those on other plants suggest that the problem of resistance to diseases may be closely allied to the fitness of a plant for the climate in which it is being grown. This point of view might find valuable ap-

plication in the breeding of disease-resistant crop plants.

#### PHYSIOLOGICAL STUDIES

The knowledge that has been gained concerning the nature of climatic races makes it possible to formulate a program of investigation on their functional differences. Relatively simple methods for comparing basic physiological functions of climatic races give promise of making it possible to relate the physiological reactions characteristic of climatic races to the ability of the races to survive in different environments.

The general method of approach will be to compare the effects of one environmental variable on several selected functions of contrasting climatic races under controlled conditions. Two types of experiment are planned: one is to be exploratory and qualitative, and the other is to be controlled and quantitative. The object of the exploratory experiments is to determine the general limits within which it may be profitable to conduct the more precise work. The quantitative experiments will be conducted in chambers in which radiation, temperature, and relative humidity are regulated, so that these conditions may be changed or closely reproduced at will.

In the study of altitudinal and latitudinal races, it is assumed that the principal controlling environmental factor is temperature. This assumption is made because of the great similarity in the nature of the variation between the two kinds of races, and because temperature is the outstanding variable common to both series. It is probable that other factors may also be important, but it is felt that the effects of temperature should be thoroughly investigated first. The functions to be studied are assimilation, respiration, and absorption of

water by roots. Water absorbed by roots will be measured volumetrically as it is removed from culture solutions. By measuring carbon dioxide exchange and rate of water uptake simultaneously, possible correlations between these functions may be studied.

The most contrasting altitudinal races of a species will be compared first; intermediate races may be introduced later on. Genetically different individuals of one population may also differ in their physiological activity over a range of temperatures, and possibly even in their tolerance to extreme temperatures. It is hoped that such data will reveal the physiological differences on which the evolution and existence of climatic races seem to depend.

The exploratory type of physiological experiment has been initiated by the construction of an apparatus designed to provide a gradient in soil temperatures for studies on the effect of this factor upon growth of climatic races of *Achillea* and *Potentilla glandulosa*. This apparatus consists of a sand-filled tank, well insulated and fitted with an insulating lid with holes for the plants. At each end of the tank is a compartment in which the temperature is maintained at a constant value. One end is kept near 0° C. by means of a refrigerating compressor; the other is kept near 40° C. by electric heaters. Both temperatures are kept nearly constant by thermoregulators. A gradient of temperature through the sand is established by the presence of these end compartments. The sand-filled part is partitioned into smaller units in order to restrict the roots to a fairly narrow range of temperature. The sand is watered from below with nutrient solution by a hydrostatic system.

Seedlings or rooted cuttings of altitudinal races are grown in rows running the length of the tank from the warm to

the cold end. The apparatus is located in a small greenhouse in a place where the aerial parts of the plants are exposed to as nearly the same environment as possible. In this manner, relations between soil temperature and growth of roots of the various climatic races are being studied in connection with the growth of tops in a given aerial environment.

An apparatus for experiments of a quantitative nature has been designed and partly constructed. It consists essentially of a cubical air chamber 14 inches on each side, in which air temperature, relative humidity, and radiation intensity are to be controlled. It is designed to maintain air temperature constant at any value between 0° C. and 50° C., relative humidity between 20 and 80 per cent, and radiation between zero and half or more of full sunlight intensity. Two sides and the top of the chamber are of glass to permit entrance of radiation from lamps.

The container holding the roots projects through the floor of the chamber into a solution the temperature of which can be controlled independently of that of the air around the shoots. The air system is to be made airtight so that changes in concentration of carbon dioxide may be measured.

Individuals of races for use in these experiments will be grown in nutrient solution in a greenhouse. After being thus exposed to closely similar environmental conditions, these will then be introduced into the control chamber for a study of their physiological functions.

It is hoped that in the future these investigations may be extended to the study of growth of climatic races under conditions which will permit control of all factors of the environment during their entire life cycle. It will then be possible to investigate the carbon dioxide exchange and



water absorption of plants grown under a wide range of reproducible environmental conditions. The development of the control chamber is temporarily suspended because Dr. Martin, who designed and was building it, is now engaged in war research.

#### INVESTIGATIONS ON THE MADIINAE

Efforts of the staff are being concentrated on the analysis of many years' accumulated data on *Layia* and related genera, and on the completion of experimental work needed to round out the investigations on the other Madiinae. The results on the *Layia* group are being prepared for publication.

The investigations on *Layia* were discussed rather fully in Year Book No. 40, pages 160-170. Developments in the study of the genus during the past year include the completion of genetic analyses of pappus characters in geographical strains of *Layia platyglossa*, data from  $F_2$  populations of hybrids in the *Layia gaillardoides* group, and the establishment of the genetic relationship of a newly discovered *Layia* whose morphology is so unlike that of other members of the genus that even its inclusion in the subtribe Madiinae was open to question (cf. Year Book No. 40, p. 168). From hybrids now obtained it appears that this plant is probably a mere subspecies of *Layia glandulosa*, with which it seems to be highly interfertile. It is apparently an extremely reduced and slender form of that species, with ray florets completely lost and the pappus much abbreviated.

The newly synthesized *Madia citrigracilis*, mentioned in the previous report, is being grown in its third generation for further tests on its fertility and cytological regularity, and for comparisons with its parent species, *Madia gracilis* and *M. citriodora*, as well as with the native *citrigracilis* obtained in the wild.

Miss Marguerite E. Hartung, formerly of the University of Hawaii, has been engaged during the current year in microtechnical work in connection with cytological studies on the Madiinae, and has aided in the analyses of hybrid populations of *Layia* and *Madia*. She succeeds Mr. Malcolm Nobs, who now is in the United States Army. Exploratory studies by Mr. Nobs on the cytogenetics of the wild lilacs of California, the genus *Ceanothus*, have been incorporated in a recently published monograph on this complex group by Professor Howard E. Minn, of Mills College.

#### STUDIES AT THE TRANSPLANT STATIONS

Final data are being obtained this year on the selection experiment involving an  $F_2$  hybrid population between a foothill and an alpine form of *Potentilla glandulosa* (cf. Year Book No. 39, p. 162). These will be subjected to a thorough analysis before publication.

New clone transplants consisting of 30 individuals each of fourteen populations of *Achillea* have been set at the Stanford, Mather, and Timberline transplant stations this year. These populations are from altitudinal intervals of approximately 1000 feet along the station transect, with a strain from the Danish seacoast and another from Lapland included. All these transplants are to be studied with special reference to genetic variation within populations and to differences between populations as a whole in these contrasting environments. It is intended to coordinate these studies closely with the physiological investigations in the hope that a clear picture may be obtained of the interrelations between genetic variation in natural populations and climatic races on the one hand and physiological functions on the other. This should lead us to a clearer understanding of the dynamics of evolution.

## DESERT INVESTIGATIONS

FORREST SHREVE

In previous years the investigation of the Sonoran and Chihuahuan deserts has consisted almost entirely in work on the vegetation and in the effort to secure a complete enumeration of the vascular plants. The core of these projects, however, is a knowledge of the influences of climate and soil in determining the vegetational and floristic features that have been found. Practical considerations have made it impossible to attempt an adequate system of instrumentation over such large areas or even to carry on a restricted system for more than a few years. Official American and Mexican climatic data are very helpful, although they are lacking in regard to many phases of great biological importance. Also, desert climatological stations, like all others, are located at centers of population rather than at critical places in the climatic map. Many of the data obtained at the Desert Laboratory over long periods are of biological significance, but they are not all applicable to other parts of the desert.

Work on the vegetation and flora of the desert areas has been continued, and during the past year an appraisal has been made of all data bearing on the physical conditions of the Sonoran and Chihuahuan deserts. A detailed study of the data has been completed for the rainfall only.

## FIELD WORK

In the summer of 1941 Dr. Shreve continued the exploration of the eastern edge of the Chihuahuan Desert and examined the elevated plateau of Hidalgo and eastern Queretaro. The principal objective was to learn the character of the Hidalgo desert and the relation between the northern and southern types of desert in Mexico.

The northern type, characteristic of the lower elevations of Chihuahua and Coahuila, does not extend south of the state of San Luis Potosí. Much of the desert of Hidalgo is edaphic rather than climatic. On extensive areas of shallow limestone soil, the vegetation is desert, and similar to that of central San Luis Potosí. On deep and retentive volcanic soils at the same altitude, the vegetation is arid bushland of a type which bounds the desert at many places along its eastern and southern edges. Where streams or abrupt canyons are found in the arid highlands of Hidalgo, the vegetation is closely related to the northern fringe of tropical forest common in northern Veracruz, and has no relation to the vegetation of similar habitats in the desert. Also the floristic relationship of the moister habitats is preponderantly with the subtropical lowlands rather than with the desert. Locating the southern limit of the Chihuahuan-Coahuilan type of desert has been made difficult by the recurrence of desert valleys separated by hilly and mountainous areas of bushland or forest. Sufficient study of the region has now been made, however, to warrant a definite delimitation of the southern boundary of the Chihuahuan Desert in central San Luis Potosí.

Proximity to Mexico City gave an opportunity to visit the Biological Institute of the National University of Mexico, from which have emanated several important investigations of the vegetation of central and southern Mexico. Dr. Isaac Ochoteren, Director of the Institute, has long been very helpful, both officially and scientifically, in connection with our work in his country. Discussions with him and with Dr. P. F. Villagran and Professor L. An-

cona, of his staff, were full of valuable comments and suggestions, and were particularly helpful with reference to the status of the arid regions of Puebla and Oaxaca.

Visits were also made to the National Meteorological Observatory of Mexico, at Tacubaya. Through the courtesy of Sr. José C. Gómez, Chief of the Meteorological Service, we were supplied with a complete transcript of the rainfall and temperature data for all the older stations in the Sonoran and Chihuahuan deserts. This material is invaluable in a study of the environmental conditions of the desert regions.

Dr. I. M. Johnston spent 10 weeks in the field in central Coahuila and eastern Chihuahua in the past summer, accompanied by Dr. Kirk Bryan, of Harvard University, who was engaged in physiographic investigations in the same area. The desert basins and low mountains lying between Musquiz and Cuatro Ciénegas, Coahuila, were explored, and also the region surrounding Sierra Mojada and the Lago de Coyote, lying partly in Coahuila and partly in Chihuahua. A collection of over 2000 herbarium specimens was made, illustrating fully the distinct floral features of the small mountain ranges that were visited.

A plant collection of nearly 2000 numbers was made by Mr. Robert M. Stewart, of Santa Elena, Coahuila, and presented to Gray Herbarium for study in connection with the Chihuahuan Desert project. This collection is very useful on account of the remote localities in which it was taken and because most of the plants were obtained in the early and late weeks of the summer, periods in which little collecting has been done in any part of northern Mexico.

A collection made by Mr. Lowden Stanford and associates, of the University of

Washington, in the summer of 1941 was placed in Dr. Johnston's hands for determination. This series of 1100 numbers was collected in poorly known hilly and mountainous regions in southern Coahuila, including the Sierra de Jimulco, the Sierra de Parras, and the hills around Fraile, Coahuila and Concepción del Oro, Zacatecas. This collection from the "cross ranges" which traverse the center of the Chihuahuan Desert is of considerable floristic and ecological interest.

Dr. Johnston is now preparing for publication the descriptions of nearly 100 new species that have been detected in the collections made by himself, Mr. Stewart, and Mr. Stanford in the field work of the past 2 years.

Further observations were made by Dr. Johnston on the plants confined to outcrops of gypsum or soils rich in gypsum, and a series of samples for analysis was taken in several localities.

In the summer of 1941 Dr. I. L. Wiggins, accompanied by Dr. Reed C. Rollins, visited central Sonora. The aim of the trip was to reach the very arid plains and hills which lie near the Gulf of California between Guaymas and the mouth of the Río Sonora. Part of the region was visited, but much of it was found impossible of access without more elaborate equipment. So many of the plants previously supposed to be endemic to the peninsula of Baja California have been found in restricted localities between Tiburón Island and Guaymas that this trackless stretch of desert coast continues to have an inviting interest. Dr. Wiggins also visited the foothills east of Hermosillo and made a collection of over 500 plants. During his stay in the field he took the opportunity to give the test of actual use to the keys for determination of plants that have been prepared for the completed parts of his flora of the Sonoran Desert.

## ENVIRONMENTAL CONDITIONS

In arid regions the character of the rainfall outweighs other physical conditions in its influence on the local or habitat distribution of plants. It is necessary to consider several aspects of the rainfall other than the annual mean. In fact, this latter datum is only of very general importance.

In a study of the relation of rainfall to vegetation in the Sonoran and Chihuahuan deserts it has been found desirable to make a comprehensive examination of the records for the whole of northern Mexico. Only in this way is it possible to understand the larger storm movements and to know about the rainfall conditions just outside the desert. The regular annual recurrence of storms originating in the Caribbean Sea and the Pacific Ocean is responsible for the seasonal distribution of the desert rainfall. The amounts and distribution of rain just outside the desert represent the minimum requirements for other types of vegetation, and in some cases are indirectly inimical to desert plants. The most arid types of vegetation bordering the Sonoran and Chihuahuan deserts, excepting other desert areas, are the thorn forest of the Pacific coast, the grassland and chaparral of Chihuahua and Coahuila, and the arid bushland of the northeastern coast and the mountains of the central plateau.

From available records it has been possible to determine several special features of rainfall. Use has been made of all sets of data extending from 1920 to 1940 and also the readings for 15 or more years from a few stations in thinly settled areas. Few complete records for more than 20 years are available. Lack of records of daily precipitation over long periods has been a handicap. For the past 5 years the Mexican Meteorological Service has kindly supplied copies of its daily weather map, carrying

daily rainfall readings, which will eventually furnish a basis for more accurate work on rainfall intensity, daily extremes, and duration of drought periods.

Variation in the annual rainfall total is well known to increase as the mean total becomes smaller. In tropical Mexico and just outside the borders of the desert in northern Mexico, the wettest years yield from 1.5 to 3 times the total for the driest years. In the Sonoran Desert there are stations at which the fall in wet years has been from 16 to 329 times that of the driest years.

Rainless periods of more than 1 month are rare outside the desert on the east coast. In the Chihuahuan Desert several stations have had rainless periods of 4 months during the 20 years. In the Sonoran Desert periods of 10 to 18 months without rain have been experienced at five stations. These long periods are particularly characteristic of Baja California and the Gulf coast of Sonora. Their importance to vegetation is obvious. At Mazatlán, Sinaloa, well within the thorn forest region, the longest rainless period was 7 months, an eloquent testimonial to the semiarid character of the thorn forest.

As one crosses northern Mexico from west to east (Ensenada, Baja California to Matamoros, Tamaulipas), the differences in total rainfall are outweighed in importance by the pattern of seasonal distribution. The rainfall of northern Baja California is confined to the winter, that of northern Sonora is biseasonal, that of Chihuahua is mainly in the 4 summer months, that of Coahuila is rather evenly distributed through the last 8 months of the year, and that of northern Tamaulipas (which is outside the desert) is well distributed throughout the year, with early and late summer maxima. These great differences in seasonal distribution are correlated with marked differences in vegetation.

As one crosses Sonora and Sinaloa from north to south, there is found to be a sharp increase of rainfall between Ciudad Obregón, Sonora and Culiacán, Sinaloa, at the transition from desert to thorn forest. Also there is a gradual decrease of winter rainfall between the international boundary and Mazatlán, and an increase of summer rainfall. At Nogales, Sonora, the rain of July, August, and September is 60 per cent of the annual total, whereas at Mazatlán it is 79 per cent. In southern Arizona and northern Sonora a biseasonal rainfall of 8 to 12 inches is found in the desert, but at Culiacán and Mazatlán a nearly uniseasonal rainfall of 24 and 28 inches respectively serves to maintain the thorn forest.

Throughout the southwestern United States and northern Mexico the gradients of altitudinal change in rainfall are controlled by distance from the sea, by prevailing winds, by the steepness of slope of the land masses or mountains that are encountered, and by the summit altitude of the mountains. The influences exerted on vegetation by rainfall are further complicated by temperature conditions, slope exposure, underlying rock and soil, and other conditions. The topographic influences on rainfall are of great importance in the control of the several types of vegetation in northern Mexico. The conditions are such, however, that there is no altitudinal control of the occurrence of desert, which exists from sea level to 7200 feet.

## PALEOBOTANY

RALPH W. CHANEY

As has been emphasized in previous reports, the climatic and topographic setting of living plants, readily determinable from a study of modern environments, may be projected back into the past to a time when similar vegetation covered the earth, leaving its record as fossils in the rocks. Interpretation of Tertiary floras, whose members have survived in modified form in the forests of today, provides many details regarding the physical history of North America. During the early years of our study of Tertiary paleobotany in the western United States, the close similarity of certain fossil floras to living forests became apparent. In our first discussions of the Bridge Creek and Mascall floras, relationships to the modern redwood forest, to the border redwood forest, and to deciduous forests in eastern North America and Eurasia were indicated. Subsequently reference has regularly been made to groups of fossil species whose equivalents have survived in modern forests, the

groups being termed the Redwood element, the Deciduous element, and the Asiatic element of the flora involved.

In later years, elements in Tertiary floras have been designated by several workers in western America, but the application of names has not always been consistent. It seems desirable at this time to standardize the use of the terms applied, and to clarify the implications of such usage. In consultation with Drs. Herbert L. Mason, Lincoln Constance, and Daniel I. Axelrod, all of whom have spent much time considering the problem, definitions and a classification have been devised. A fossil flora may be broken down into elements whose living equivalent species are found in association at the present time. An *element* may be defined as a group of fossil plants whose modern related species occupy a major geographic and climatic province.

In all Tertiary floras studied, divergent types of vegetation may be noted which

are assignable to several elements. The five elements commonly designated in Tertiary floras of western North America are:

1. *The West American element* is made up largely of conifers, with broad-leaved evergreens commonly present. The region which their most typical living equivalents now occupy is characterized by temperate climate, with winter rainfall and summer drought, and with a moderate range of temperature.

2. *The East American element* is made up largely of broad-leaved deciduous genera, with conifers of minor importance. The region on the eastern side of North America now occupied by their living equivalents is characterized by temperate climate, with well distributed rainfall of which a considerable amount falls during the summer, and with seasonal extremes of temperature, most trees losing their leaves during the cold season.

3. *The East Asian element* is made up of genera now confined to eastern Asia, and includes also genera occurring in other parts of the world whose species show close resemblance to those now living on the western side of the Pacific. The climatic requirements of the living equivalents of this element are essentially the same as those outlined for the equivalents of the East American element, except that the East Asian element also includes genera which now range into the tropics.

4. *The Southwest American element* is made up largely of microphyllous plants whose living equivalents have their centers of distribution in the mountains of northern Mexico, extending northward into New Mexico and Arizona, and along the coast from Cape San Lucas to central California and into the interior. Seasonal extremes both of temperature and of precipitation characterize these regions, in which the climate is temperate except at the south.

5. *The Caribbean element* is made up mostly of evergreen angiosperms with large, entire-margined, thick leaves. The region occupied by the modern equivalents of Tertiary members of this element, including

southern Mexico and much of Central America, has a subtropical to tropical climate, with high, generally well distributed rainfall and temperatures free from frost.

The Caribbean element in the Tertiary of western North America is best developed in floras of Eocene and Lower Oligocene age. It survived into the Miocene of Washington and Oregon in coastal and other favorable situations, and has been noted with greatly reduced representation in Pliocene floras as far north as central California. The West American element is dominant in Upper Oligocene and Miocene floras of the western United States, continuing into the Pliocene and down to the present at middle latitudes, and in the mountains farther south. The East American and East Asian elements are also abundantly represented in floras of Middle Tertiary age, becoming rare in the Pliocene and disappearing at the close of the epoch. The Southwest American element makes its first well established appearance in the Miocene of southern California, although there is reason to think that it may have been represented in the Florissant flora of Colorado, which MacGinitie believes to be of Oligocene age. It ranged northward into Oregon and Idaho at the close of the Miocene, and was restricted southward during the Pliocene.

A complete enumeration of modern plant climaxes in North America must of course include a grassland unit, which might be termed the Interior American element. Since our classification refers not to modern but to Tertiary vegetation, and since fossil collections from the western United States include no important representatives of the grassland climax, we have not designated an element corresponding to it. The important studies of fossil grasses by Elias may at some future time warrant the inclusion of an Interior American element made up of Tertiary grasses

and forbs. In the same way, it may eventually be desirable to set up a Boreal American element to include Tertiary plants whose modern equivalents are now most characteristic of high North American latitudes. Such plants appear to make up an important part of several older Tertiary floras from the arctic islands, but since they are not well represented in the fossil floras of Oregon and adjacent areas, the Boreal American element is not included in the classification here presented.

From even a cursory reference to the distribution of tree genera in modern forests, it is apparent that there must be some overlapping of the constituents of these elements. The East American and East Asian elements each have distinctive genera; but there are others common to the two which have species so similar that they may equally well be considered as the fossil equivalents of species now living either in eastern America or in eastern Asia. The marked similarity between the vegetation on the east sides of the two continents has been well known since the days of Asa Gray, and is to be expected because of the climatic similarity of the regions. But there are also differences, which are emphasized by the study of forest evolution in the western United States; it therefore seems essential that separate element rank be assigned to these major forest units of the two continents. There are likewise close relationships between the East and West American elements; it is not always possible to determine whether a fossil species of sycamore, *Platanus dissecta* Lesquereux, has as its modern equivalent the eastern species, *P. occidentalis* Linnaeus, or the western species, *P. racemosa* Nuttall; one of the most common fossil species of black oak, *Quercus pseudo-lyrata* Lesquereux, seems almost equally related to living oaks on both sides of the continent. Such dual

representation of fossil species is to be expected in a classification as general as ours, and serves to emphasize the common origin of forests now widely separated, but intermingled in the generalized vegetation of the Tertiary period in the western United States.

A further comment seems necessary to clarify our attitude toward comparisons between fossil and modern plants. All our lists of equivalent living species are at best a tentative expression of opinion regarding the modern affinities of fossil species. These suggested relationships are based largely on leaf similarities, with the supporting evidence of fruits or seeds also available in some cases. Such comparisons are highly suggestive, and are made whenever the fossil specimens are sufficiently well preserved; but they are not to be considered as final evidence of phylogenetic relationships. Whether a fossil oak finds its nearest living descendant in the forests of North America or in those of eastern Asia, the fact that similar living species may be noted on both continents is highly significant in any consideration of the Tertiary history of vegetation in the northern hemisphere. Such relationships also make possible a more natural interpretation of the origins of modern forests.

Each of the elements designated in Tertiary floras may be further subdivided into *components* which represent their major floristic units. Component names are assigned to emphasize dominant plants, secondary topographic features, or climatic zones. The components most commonly recognized in discussing the Tertiary history of the West American element are the Redwood, the Border-redwood, the North-coast coniferous, the Sierra-Cascade, and the Rocky Mountain. Usage will vary somewhat until the significance of these components in Tertiary vegetation becomes better understood. The Border-

redwood component may represent an ecotone between the Redwood component and two components of the Southwest American element, the Oak woodland and the Chaparral. Locally the modern forest equivalents of the North-coast coniferous and the Sierra-Cascade components grade into one another, and their place as distinct units in the forests of the Tertiary may in some cases be open to question.

A natural division of the East American element would recognize the Beech-maple, the Oak-hickory, the Coastal pine, and the Swamp cypress-tupelo components. All these except the Coastal pine are well represented in the Middle Tertiary floras of the western United States. It is possible that additional components may be designated as current studies of the Mascall and Bridge Creek floras of Oregon are continued.

The East Asian element is subdivided, largely on the basis of climatic and topographic units, into Northern temperate highland, Northern temperate lowland, Southern temperate highland, Southern subtropical lowland, and Southern tropical lowland components. It seems probable that future field studies in Asia will make possible floristic and geographic names corresponding to those assigned to the components of the East American element, names which will carry a more significant connotation.

The Southwest American element is divisible into the above-mentioned Oak woodland and Chaparral components, and also into Conifer woodland, Closed-cone pine, and Coastal sage. The Oak woodland component, occurring under a wide range of topographic and climatic conditions, represents a more diverse floral unit than the other components of the Southwest American element; but it does not appear to indicate a wider range of com-

position than do certain components in the East American and West American elements.

The subdivisions of the Caribbean element, as in the case of the East Asian, are tentative as here presented. They include the Warm-temperate highland, Subtropical lowland, and Tropical lowland components. More definite component names will be assigned in future discussions of Eocene floras, in which the Caribbean element is largely represented.

It should be emphasized that element and component names are applied to groups of fossil plants to emphasize their resemblance to modern vegetation, and that they do not necessarily coincide with the names or units involved in the study of living plants. In cases where groups of fossil plants have living equivalents occupying well defined geographic or climatic provinces and subprovinces, it is convenient to designate them in terms of these living equivalents and their habitats. Our element and component names indicate the *present* distribution of surviving equivalents of Tertiary species, not their past distribution; there is no inherent basis for assuming that a Miocene oak assigned to the East American element was living in the eastern United States during that epoch; only its discovery there in Miocene rocks would indicate that its range at that time coincided with its present distribution. Further, there is not the slightest implication that the provinces covered by element names represent the centers of dispersal of the plants involved. The modern occurrence of *Cercidiphyllum* is no more an indication that it had its origin in China than is the presence of *Sequoia* in California evidence that it is a native son. Centers of origin and modern range of species may in some cases coincide; but when there is a wide time discrepancy between the living tree and its



fossil equivalent, there are likely also to be wide discrepancies between their Tertiary and Recent distribution, representing the distances covered in the course of forest migrations through geologic time.

One further consideration warrants brief comment at this point. Many floras, especially those of Middle Tertiary age, include several elements representing forests now widely separated in regions with diversified climates. We conclude that such vegetation was of a more generalized type than are most living forests. Physical changes toward the later part of the Tertiary period brought diversified topography and climate, producing the geographic and climatic provinces which we recognize, each with its distinctive forest. Differentiation of the generalized vegetation of the past into modern floristic units may best be expressed by the recognition of diverse ingredients in Tertiary forests. Such ingredients, which we term elements and components, represent groups of trees whose varying response to earth change has resulted in their restriction to the modern regions best suited to their requirements. A survey of modern forest environments and a comparison of their vegetation with that of the past provides the most adequate basis for our understanding of continental history, since it makes possible a reconstruction of the topographic and climatic setting of Tertiary forests.

During the past year a significant comparison has been made between the swamp cypress forest of southern Indiana and the Mascall flora from the Miocene of Oregon. Unlike the *Taxodium* forest living farther south, the swamp cypress near

the northern limits of its range is closely associated with black oak, hickory, and maple. These trees grow on the borders of the swamp, and their leaves may be found mingled with those of the cypress in sediments now accumulating. Similar accumulation of leaves in the lake deposits of Oregon's past has given us a fossil assemblage with essentially the same composition, and a closely similar environment is indicated. Unlike the somewhat older Bridge Creek flora, in which *Sequoia* is the dominant conifer, the Mascall assemblage suggests the presence of swamps and lakes during later Miocene time. Known facts regarding the geologic history of the John Day Basin during this stage are consistent with such a topographic picture. Immense amounts of volcanic ash were accumulating along the courses of streams, which were locally overloaded with these sediments, or dammed by lava flows. By contrast, the Bridge Creek shales laid down at the close of the Oligocene and the beginning of the Miocene seem to represent valley accumulation under more normal conditions of gradation. The modern occurrence of the redwood is confined to well drained valleys, and that of the swamp cypress to those which are poorly drained. The difference between the Bridge Creek and Mascall floras may be due more to topographic than to climatic changes during Middle Tertiary time.

The studies of Dr. Chaney's associates, Daniel I. Axelrod, Erling Dorf, and Harry D. MacGinitie, have continued along the lines outlined in recent reports. Their publications are listed in the bibliography.

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## DEPARTMENT OF EMBRYOLOGY

*Baltimore, Maryland*

GEORGE W. CORNER, *Director*

The program of the Department of Embryology has followed, as fully as present conditions permit, the plans set forth in last year's report. The collection of embryos has been increased by many acquisitions, notably a number of very early human embryos which are described below. The publication of several papers and a comprehensive volume on the embryology of the rhesus monkey marks the completion of the general exploration of that subject which has been under way for some years, although many special problems remain to be studied. The work in experimental embryology, using the remarkable advantages afforded by the opossum, in which the young, while still in embryonic condition, are accessible in the brood pouch, proceeds successfully and is yielding results which will appear in the next report. Studies, by physical methods, of placental function and of the measurement of the sex-gland hormones in the blood and tissues have been interrupted by the transfer of the investigators concerned to duties directly connected with war service, but the work on the

placenta had fortunately gone so far that it has been possible to set down a considerable body of results and to draw instructive general conclusions. A general investigation of the mammary gland of the monkey and its reaction to the sex-gland hormones has reached a similar stage. Details of these and other projects will be found in the following pages. Although at the present writing it is difficult to foresee the course of events, even within the relatively sheltered walls of a research laboratory of embryology, it appears that we shall be able to preserve and exploit our unique collections and to keep up a significant part of the investigative program, while doing everything possible to share in the national effort.

During the year the facilities of the Department were made available to a number of scientific visitors, including Dr. Joseph Gillman, of the University of the Witwatersrand; Dr. Emil Witschi, of the University of Iowa; and Dr. T. L. Terry, of the Massachusetts Eye and Ear Infirmary.

### EMBRYOLOGY

#### EARLY HUMAN EMBRYOS OF THE PRE-VILLOUS STAGE

This year the Department is again able to report notable progress in the study of early stages of human development. In 1939 (Year Book No. 38) Dr. Streeter mentioned the acquisition of two new human embryos, of about the 11th and 12th days, which had been obtained by Drs. A. T. Hertig and J. C. Rock, of Boston.

These two complete and perfect specimens, together with the previously known but incomplete Miller ovum, formed a group at what was then the earliest known stage of human development, so that an important period which had been known only hypothetically (so far as the human species is concerned) has now become known by actual observation.

Some information about these two valu-

able embryos was made public by Dr. Hertig and Dr. Streeter in lectures and demonstrations to scientific societies; photographs and reconstructions illustrating them were exhibited at the 1939 Annual Exhibition of the Carnegie Institution, and photographs have even been made available for use in one or two textbooks. Thus these embryos have already to some slight degree contributed to professional knowledge. Drs. Hertig and Rock have now completed their detailed study, and full descriptions of both embryos appear in the current volume (XXIX) of the Carnegie "Contributions to Embryology." It is now a pleasure to announce that these indefatigable investigators, whose work has been aided by a grant from the Carnegie Corporation of New York, have continued with success their painstaking search for early human embryos. Up to the present they have obtained and deposited in our collection no less than 52 specimens, among which are 12 embryos of the 2d and early 3d weeks. Of these, 7 are to all appearances normal and 5 show various abnormalities. It need hardly be added that the earliest disturbances and abnormalities of human development are quite as important as the normal stages.

During the past year Drs. Hertig and Rock have obtained two embryos definitely earlier than any previously known, one of them believed to be  $9\frac{1}{2}$  days old (Carnegie no. 8004) and the other  $7\frac{1}{2}$  (Carnegie no. 8020). These, like all the others, have been successfully cut into sections, stained, and mounted by Dr. Heuser, Mr. Heard, and Miss Caspari, and fully photographed by Mr. Reather.

This special collection of human embryos constitutes an inestimable scientific treasure, rich in precise information about the development of the embryo and especially about the first stages of its attach-

ment to the mother, before the development of placental villi and of the yolk sac.

Descriptions of the first two of the Hertig-Rock embryos, nos. 7699 and 7700 of the Carnegie Collection, have been published in full, as mentioned above. Their nature will be made clear to those readers of this report who are not biologists by the accompanying diagrams (figs. 1, 2). Both embryos are earlier than the stage represented by the first (left-hand) sketch in figure 1. No. 7699 is believed to be 11 days old, no. 7700 to be 12 days old. They are both very small. Either of them would quite easily pass through the open space of the small letter "o" of the type in which this report is printed. As will be seen in figure 2, both of them have barely finished growing into the lining of the uterus, being separated from its cavity by only a thin layer of tissue. At this stage the embryo itself is very simple, consisting of a disk of ectoderm with a disk of endoderm applied to its ventral side. In the case of the younger embryo this bilaminar embryonic disk is roughly circular, so that it is not yet possible to determine with certainty the direction of the future long axis of the body it is destined to form. Its diameter is 0.138 mm.; that is to say, 7 such embryonic disks, if arranged in one layer on the printer's period at the end of this sentence, would not completely cover it. In the older embryo this "disk" has grown a little longer and narrower.

Over the back, so to speak, of the embryonic area, in each of these embryos, the amniotic cavity is already visible. Ventral to the endoderm is a cavity in the region where the yolk sac will become well defined a day or two later. This cavity is walled by the delicate exocoelomic membrane (Heuser's membrane). Just how the first cells of the endoderm are related to this membrane, and how the membrane, in

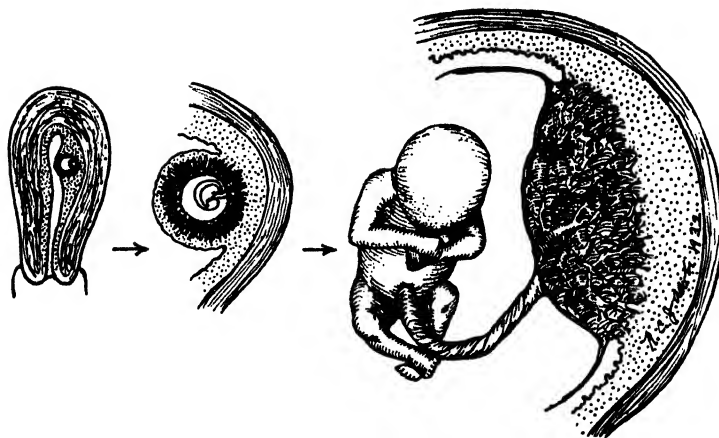


FIG. 1. Diagram showing location and development of the human embryo. The left-hand figure represents a stage a little later than the Hertig-Rock embryos mentioned in the text (embryo is drawn disproportionately large with respect to the uterus).

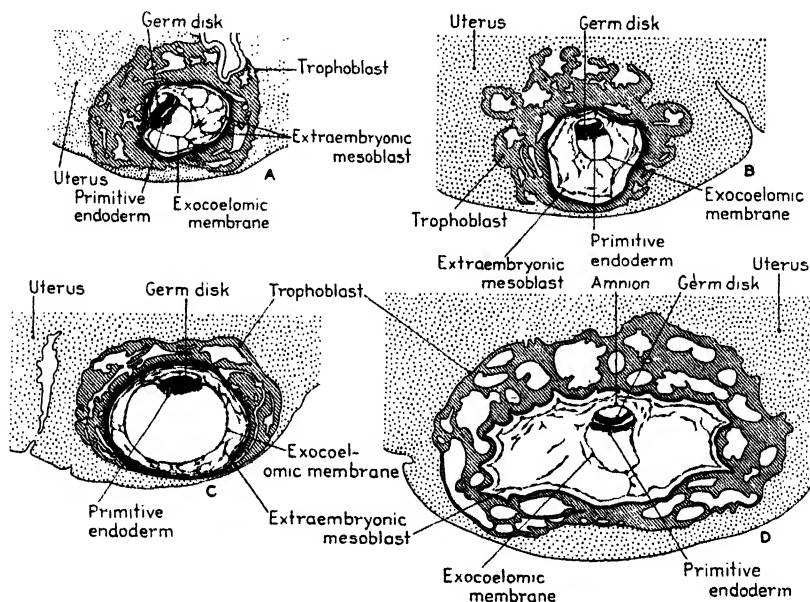


FIG. 2. A and C are diagrams of the Hertig-Rock embryos, Carnegie nos. 7699 and 7700 respectively. B and D show two previously known but slightly more advanced embryos, namely the Miller ovum as reconstructed by Streeter, and the Werner (Stieve) embryo.

turn, is related to the yolk sac, are questions still eagerly discussed by those who have studied these early embryos, but destined no doubt to be cleared up in subsequent publications.

The cavity in which each embryo lies, relic of the original blastocyst cavity, is surrounded by the trophoblast or outer cell layers, whose function is to establish relations with the maternal blood circulation. Already in these early embryos the trophoblast has differentiated into an inner cytotrophoblast and an outer syncytiotrophoblast. The latter, as indicated in figure 2 (and of course fully illustrated in the article by Hertig and Rock), has begun to form a series of cavities, the trophoblastic lacunae. Into these spaces the maternal blood capillaries early begin to open, so that some of them, even in the younger specimen, contain maternal blood. The inner layer, the cytotrophoblast, is in the older specimen beginning to form cell groups pushing outward into the syncytiotrophoblast. In the cores of these knobs (which are the first beginnings of the placental villi) the earliest signs of the embryonic blood vessels are seen as a primitive angioblast. The rudiments of the uteroplacental circulation are thus laid down. There is no necrosis of maternal tissues. Early decidual cells are forming in the stroma of the endometrium adjacent to the embryonic trophoblast.

In the case of the younger embryo, 730 cc. of the maternal urine collected during the 2 days preceding operation, when concentrated and injected into a rat, produced ovarian changes characteristic of the Zondek-Aschheim test for pregnancy, a truly remarkable finding in view of the early stage of pregnancy.

#### TWO HUMAN EMBRYOS IN THE PRESOMITE STAGE

Dr. Joseph Krafka, Jr., of the University of Georgia, contributes to volume XXIX of

the "Contributions to Embryology" a description of a human embryo of the presomite stage. This is the Torpin ovum, so called after Dr. Richard Torpin, of the Department of Obstetrics and Gynecology of the University of Georgia, who obtained it at operation. Its age is estimated to be 13 days. The specimen is complete and in a good state of preservation. It is particularly interesting with regard to the blood vessels at the site of implantation, since it well shows the early development of the venous sinusoids characteristic of this stage of attachment. Dr. Krafka has given not only a clear description of the specimen, but also a good deal of interpretative analysis which must be taken into consideration when a general account of human embryos of this period comes to be written.

Dr. H. O. Jones and Dr. John I. Brewer, of the University of Chicago, present in the same volume an account of an embryo in the primitive-streak stage, estimated to be 18½ days old. It is designated as the Jones-Brewer ovum I (not to be confused with the Edwards-Jones-Brewer embryo, *Contributions to Embryology*, vol. XXVII). It shows the earliest stage of the head process thus far described in the human embryo. The first signs of the neurenteric canal appear as three small spaces within the primitive knot (Hensen's node). The specimen is therefore especially instructive for study of the so-called gastrulation of the human embryo.

#### EMBRYOLOGY OF THE RHESUS MONKEY

For more than twenty years this laboratory has been investigating the embryology of the rhesus monkey. It is hardly necessary to explain the value of such a study of the development of one of the infra-human primates, carried on in parallel with that of the human. The experience thus obtained and the resulting large collection of monkey embryos, obtained ex-

perimentally and therefore properly timed and preserved, has served to guide the study of very early human embryos such as are discussed above. Knowledge of the physiology of reproduction in the monkey, gained in the course of this work, has contributed greatly to our understanding of menstrual phenomena and ovarian function in mankind as well as in the monkey itself. Moreover, as will be emphasized a little later, this study of the monkey, revealing for the first time the earliest stages of primate development, contributes to embryological thinking in general.

In 1921, the embryology of the monkey was quite unknown and the general physiology of reproduction in this animal was not understood. In 1942 the rhesus monkey is in these respects one of the best-known mammals. The work on this species has been led in this laboratory by Drs. G. L. Streeter, C. H. Heuser, and C. G. Hartman, whose part in it was referred to in last year's report (Year Book No. 40). These workers have been in constant touch with colleagues studying monkeys in other laboratories, including especially Drs. G. B. Wislocki, of Harvard University; G. W. Bartelmez, of the University of Chicago; J. B. Markee, of Stanford University; and G. W. Corner while he was at the University of Rochester. All these investigators have added to the subject through articles in the "Contributions to Embryology" as well as in other journals.

It has been possible to publish this year three papers which describe the development of the rhesus monkey from the egg in the ovary until birth. Drs. C. G. Hartman and G. W. Corner describe six ovarian eggs, two of which were undergoing the first maturation division. In the monkey, as in the majority of mammals, the first maturation division occurs within the follicle just preceding its rupture. The egg therefore leaves the ovary with the

polar body formed and the second polar division in progress. Drs. W. H. Lewis and C. G. Hartman take up the story at this point with the description of eight eggs recovered from the oviduct, two of which were in the 2-cell stage and six were non-fertile. To these may be added four eggs previously described by the same authors, from the 2-cell to the 16-cell stage.

The long campaign of investigation of monkey embryology is brought to a climax in this volume by an extensive monograph on development of the macaque embryo by Drs. C. H. Heuser and G. L. Streeter. This work is first of all a photographic atlas on the subject. Its 33 plates, comprising 259 separate photographs, illustrate every stage of development from the early blastocyst of 8 days to the fetus of 57 days. The article includes a systematic list of 123 specimens used in the work, which are now available for reference in the Carnegie Embryological Laboratory. The accompanying text covers especially the period from the early blastocyst to the stage of somite formation; that is to say, the period of development least well known in the human species and that in which all the outstanding problems of primate and even of general mammalian embryology are centered.

This account is remarkable for several reasons. Well aware of the novelty of their material, which as they say has turned an entire new page in primate embryology, the authors have described it in a fresh and unconventional way. They have emphasized the idea that the embryo is not merely a morphological abstraction. It is indeed at every moment of its life a growing organism with constituent parts and tissues which have their functions to perform. Turning away from the diagrammatic interpretation and homologizing of earlier writers, the authors place little emphasis upon morphological theory, and



set aside, at least temporarily, phylogenetic comparisons and the time-honored search for evidence of recapitulation. The resulting discussion is often therefore very stimulating. For example, the authors see the embryo as a continuous center of undifferentiated formative tissue surrounded by an increasing body of specialized tissue. At first, when the ovum is a single cell, it is itself the undifferentiated mass. Then, as segregation proceeds and the wall of the blastocyst is formed, the inner cell mass continues to contain unoriented formative cells, which give rise to the germ disk. As the germ disk in turn differentiates, the primitive knot and probably the primitive streak remain as the undifferentiated center, which gives rise to specialized tissues as it gradually retreats tailward until all the undifferentiated tissue is used up.

Likewise their description of the implantation of the embryo and the earliest steps in the development of the placental circulation is exceptionally complete and clear. It aids greatly in explaining the conditions in man, known from an incomplete series of isolated specimens.

The correlation of age and form in the monkey furnishes dependable criteria of age in the human embryo. The growth curve of the macaque embryo, as well as the external form, is essentially the same as for human embryos during the first six weeks. The diverging characteristics appear later in development.

On other points there will be much discussion. Any reader who follows, for example, the account of the origin of the yolk sac will see that the two authors hold different views, and he may find himself trying to make up his own homologies as he studies the photographic evidence presented. Some readers may feel that the emphasis on the immediate functional value of the embryonic organs leaves aside important considerations regarding the

past and future history of these same organs. The authors have certainly rescued such structures as the early trophoblastic wall and the primitive streak from being merely tracings on a phylogenetic diagram, making us see them as living and functioning tissue; it will be sufficient, on the other hand, to mention the allantoic rudiment as an example of structures that can only be understood in the light of their homologies. Drs. Heuser and Streeter promise us, however, later papers in which their findings are to be related to the more familiar interpretation and terminologies.

In his Hatfield Lecture at the College of Physicians of Philadelphia, 1941, Dr. Streeter has given a helpful summary of his concept of embryogenesis in monkey and man, based largely on the monograph just discussed.

In order to make the Department's work on the embryology of the rhesus monkey readily available to laboratory workers, the Carnegie Institution has reissued in one volume these three papers from volume XXIX together with a paper on the growth of the monkey by Dr. A. H. Schultz, from volume XXVI, and one by Drs. G. B. Wislocki and G. L. Streeter on the placentation of the rhesus macaque, from volume XXVII. This special volume, which is Embryology Reprint Volume I, entitled *Embryology of the rhesus monkey (Macaca mulatta)*, forms an almost complete embryological treatise on this species. Its usefulness has been appreciated by the investigators to whom copies have been distributed.

#### ORIGIN OF THE RETE APPARATUS

In Year Book No. 40 a brief report appeared of the finding of Dr. R. K. Burns, Jr., that in opossums the ostium of the Müllerian duct and the rete canals of the gonad are members of a series of primitive nephrostomes. In an article in *Science* (see

bibliography) these conclusions have now been published in detail, with an explanatory diagram.

Dr. Burns' investigation of the effect of the sex-gland hormones on the embryonic reproductive system of the opossum, men-

tioned in the last Year Book, has progressed notably. Some of the results were presented at the 1942 meeting of the American Association of Anatomists and at the June 1942 session of the Cold Spring Harbor Symposium.

## PHYSICOCHEMICAL STUDIES

### OXYGEN CONSUMPTION OF THE EMBRYONIC BRAIN

In the last report (Year Book No. 40) mention was made of the increasing application of physics and chemistry to embryology, and of our hope that such work may be carried forward in our laboratory. A good example of the kind of beginnings that are being made in this field is a paper by Drs. Josefa B. Flexner, Louis B. Flexner, and William L. Straus, Jr., on oxygen consumption and the oxidation mechanism in the cortex of the fetal brain, as related to the development of histological structure. Using brain tissue from pig fetuses, readily available at the slaughterhouse, the investigators have applied the standard techniques for measuring oxygen consumption and the activity of the respiratory enzymes. To cite their summary: Two critical periods, the first about halfway and the second about four-fifths of the way through gestation, have been found in the morphological differentiation of the fetal cerebral cortex. Both are characterized by rapid increase in size of the nerve cells, by changes in their form, and by abrupt changes in the quantity or pattern of the Nissl substance. During the first period, cytochrome-cytochrome oxidase activity shows a distinct rise, and during the second period, the  $Q_{o_2}$  increases to the level characteristic of the adult. Variations in cytochrome-cytochrome oxidase activity at different parts of the gestation period are not reflected in corresponding variations

of  $Q_{o_2}$ . Cytochrome oxidase activity has been found constant at all stages of fetal development investigated. The increase in cytochrome-cytochrome oxidase activity with increasing fetal age consequently appears due to an increase in concentration of cytochrome c. The  $Q_{o_2}^{CN}$  of fetal and adult cortex is about 1.

### PHYSIOLOGY OF THE PLACENTA

In Year Books Nos. 39 and 40 mention was made of the program of research on the physiology of the placenta as an organ of transfer, under the direction of Dr. Louis B. Flexner, aided by Drs. Alfred Gellhorn and Herbert A. Pohl. Rapid progress has been made in the work, but it has necessarily been discontinued in 1942, because of Dr. Flexner's absence on duty with the National Research Council and the diversion of his colleagues to wartime projects. For this reason the present seems an appropriate time to summarize the results which have been achieved to date. Readers of this report who desire more details than can be given here will find a review by Flexner and Gellhorn in the paper cited in the bibliography. A few passages and a table and diagram from this article are incorporated in the following statement.

The first effort has been to determine the rate of transfer of relatively simple substances from mother to fetus through the placentas of various animals. For this purpose radioactive sodium has been

chosen as the beginning tracer material, because it is easily prepared by the cyclotron or electrostatic-pressure generator, its behavior in the body is not complex, and it is one of the physiologically important chemical building stones of the organism. The radioactive salt was prepared with the high-voltage generator of the Department of Terrestrial Magnetism of the Carnegie Institution, and with the cyclotron of the Department of Physics of Harvard University. A solution of known potency is injected into the blood vessels of a pregnant animal, and after a suitable time the fetuses are recovered by autopsy or Caesarean section. The amount of radioactive sodium which has passed from the maternal blood across the placenta to the fetus is determined by measuring the amount of radioactivity in the ashed remains of the fetuses.

Before planning the series of experiments, the investigators asked themselves the following questions, as expressed in their review:

Does the permeability of the placenta vary with the period of gestation? If the answer be positive, what are the underlying causes for the variation? Are there differences in permeability among the several morphologic types of placenta? Is the quantity of substance transferred across the placenta related to the rate at which the fetus is growing? Does the placenta act as an inert membrane or filter placed between the maternal and fetal circulations, or does it modify the transmission of substances by contributing energy to the process and so acting as an organ of secretion? How is the failure of a substance to pass the placenta related to its physical and chemical characteristics? What effects do pathologic processes have upon placental transmission and so upon the nutrition of the fetus?

If the placentas of all mammals were

alike in structure and function, the investigation would be relatively simple. The fact is, however, that placentas differ greatly in the degree of intimacy with which the maternal and fetal blood streams approach each other. Essentially, the placenta consists of a special area of the uterine lining, covered by a pavement of epithelial cells, supported on a layer of connective tissue, and underlain by a sub-surface bed of blood vessels. Against this lies an area of fetal membranes, also consisting basically of a layer of epithelial cells supported by connective tissue and underlain by blood vessels. In the domestic pig, for example, this arrangement exists in full, and therefore a molecule of sodium chloride going from the blood of the mother to that of the fetus, or a molecule of carbon dioxide going out, has to pass through all the tissues mentioned above as through a filter. It must traverse six layers, namely, the maternal blood-vessel wall (endothelium), connective tissue, and epithelium, and the fetal epithelium, connective tissue, and endothelial blood-vessel wall.

In other species the maternal and fetal layers of the placenta are much more manifolded and interlocked with each other than in the pig, and in various species the fetal epithelium and fetal connective tissue are lost. Thus the thickness and complexity of the barrier between the two blood circulations vary considerably in different orders of mammals. There are in general four classes of placenta, as indicated in table 1 and in the diagram, figure 3, based on Grosser's classification.

The investigators studied, as is noted in the table, one species in each of the first of these placental groups and three with hemochorial placentas.

It must be understood that the above-cited analysis and classification is not rigid. There are variations within each group,

and in individual species changes occur during the course of pregnancy. In the sow, for example, the epithelial layers become thinner as pregnancy advances. In the cat, guinea pig, and rabbit even the fetal (chorionic) epithelium largely disappears, bringing the maternal blood into contact with fetal blood vessels, and thus

and fetal circulations, the greater the rate of transfer. The relative figures, expressing the amount of Na in milligrams transferred across a unit weight of placenta per hour, at a comparable stage of late pregnancy, are: sow, 0.026; goat, 0.41; cat, 0.69; guinea pig, 6.1; rabbit, 6.8; rat, 8.3. It is very remarkable that such differences

TABLE 1  
CELLULAR LAYERS BETWEEN MATERNAL AND FETAL CIRCULATION  
(GROSSER'S CLASSIFICATION OF PLACENTAS)

TYPE OF PLACENTA	MATERNAL			FETAL			EXAMPLES
	Endothelium	Connective tissue	Epithelium	Epithelium	Connective tissue	Endothelium	
Epitheliochorial . . .	+	+	+	+	+	+	Sow
Syndesmochorial . . .	+	+	—	+	+	+	Goat, sheep, cow
Endotheliochorial . .	+	—	—	+	+	+	Cat
Hemochorial . . . . .	—	—	—	+	+	+	Guinea pig, rat, rabbit, man

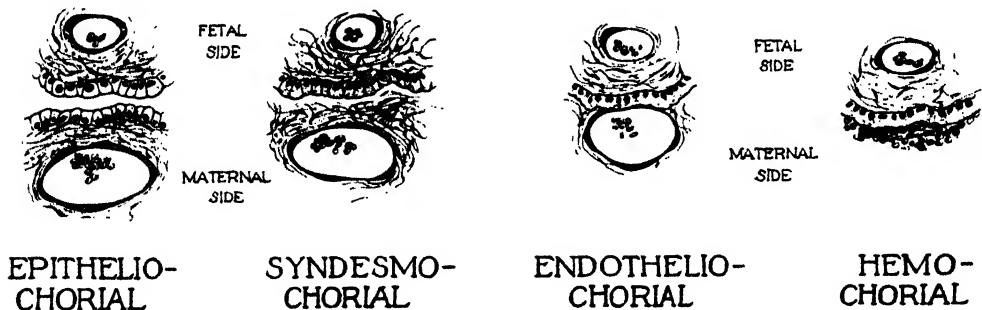


FIG. 3. Diagrams indicating the number and kind of tissue layers interposed between maternal and fetal circulations in each of the four placental types. (From *American Journal of Obstetrics and Gynecology*, by courtesy of C. V. Mosby Company.)

reducing the barrier between the two blood streams, in places at least, to an exceedingly thin layer.

Flexner, Gellhorn, and Pohl found in the first place that the rate of transfer of sodium across unit weights of the four types of placenta varies according to the morphological structure. The smaller the number of tissue layers placed between maternal

should exist between animals whose normal body temperature, pulse rate, and basal metabolism differ by no such great degrees; but the fact is that among mammals the reproductive system is more varied than any other.

In all six species there is a decided increase in the rate of transfer per unit weight of placenta as pregnancy advances.

The reasons for this are not fully understood.

The investigators next sought to know whether there is any relation between the rate of growth of the fetus and the supply of sodium received. The answer to this question can be obtained by comparing the supply of sodium to a gram of fetus per unit time with the rate at which that gram of fetus reproduces itself. The first of these quantities is found by simply dividing the total sodium transferred to the fetus per hour by the fetal weight. The second quantity is the relative growth rate of the fetus and is obtained from data relating fetal weight to gestation age. If the placenta is nicely adapted to the needs of the fetus, one would expect a large amount of sodium to be transferred per gram fetus when the relative growth rate is high, since sodium is an integral part of each unit mass of tissue, and a lower transfer rate per gram fetus when the relative growth rate is low. It was found that in all the six species studied there is a close relation between the rate of transfer per gram of fetus at any given stage of pregnancy and the rate at which the fetus is growing at that time. When the fetus is small but growing rapidly, the rate of transfer of sodium is high; as it grows older and its relative growth rate drops,

the supply of sodium per unit weight of fetus is commensurately low. There seems to be some mechanism underlying placental function by which the rate of supply of substances to the fetus is proportioned to its needs as a growing organism.

A further important deduction concerns the safety factor, i.e., the ratio between the amount of sodium chloride transferred to the fetus and the amount retained by it for use in its life processes and growth. When this ratio is calculated from the observed data, it turns out that the margin of safety is large in all the species studied except the sow. The amount of sodium salt transferred is 25 to 50 times the amount retained by the fetus. In the sow, however, the safety factor is much lower, being only 3.5 at the 16th week of gestation.

This interesting work has recently been extended to the rhesus monkey, and it has also been possible to make observations on human pregnancy by cooperation of the Department of Obstetrics of the Johns Hopkins Medical School. In these later experiments "heavy water" (deuterium oxide) has been used as tracer substance as well as radioactive sodium. The final papers of the series are now in press and will be reported upon next year.

## THE REPRODUCTIVE ORGANS AND THEIR HORMONES

### PROGESTERONE

The rapid advance in knowledge of the reproductive hormones makes it necessary to review the subject frequently for the benefit of physicians and of investigators in collateral fields. In 1942 the American Medical Association brought out a revised edition of its handbook *Glandular physiology and therapy*. This contains a chapter contributed from our laboratory by

Dr. Corner, which gives a summary of current knowledge about the corpus luteum hormone, progesterone, with especial reference to its use in medical practice.

### HORMONE DETERMINATION BY ULTRAVIOLET SPECTROPHOTOMETRY

One of the most serious needs in the study of the sex-gland hormones is for more sensitive methods of detecting the

hormones in the tissues and in body fluids such as the blood and urine. Since the steroid substances have more or less characteristic absorption spectra, spectrophotometric methods are beginning to be tried. Dr. S. R. M. Reynolds, who joined the Department's staff in 1941, spent most of the year in familiarizing himself with the technique of ultraviolet spectroscopy and in planning for apparatus to be assembled in his laboratory. Meanwhile, with the cordial help of the Department of Physics of the Johns Hopkins University and with the collaboration of Dr. Nathan Ginsburg, Dr. Reynolds made a very hopeful beginning on the microdetermination of progesterone. A preliminary account of this work was given before one of the scientific societies in the spring of 1942. A full account is in press and will be reported next year. The work has had to be put aside for the duration of the war, since Dr. Reynolds has been commissioned in the Army Air Force and called to duty at the School of Aviation Medicine, Randolph Field, Texas.

Drs. Carl G. Hartman and Harold Speert have investigated the effect of progesterone on castrated monkeys without previous treatment with estrogenic hormone. Under natural conditions in the body, any female animal in whose ovary a Graafian follicle ripens, sheds its egg, and becomes a corpus luteum will of course already have been under the influence of the general ovarian (estrogenic) hormone. The question thus arises whether progesterone can exert its characteristic effects at all if the uterus, vagina, and mammary glands are deprived of the estrogenic effect by long-standing castration. In general, experiments on lower mammals have shown that progesterone can be made effective in castrate animals by giving it in large dosage. The situation in monkeys

has not been clear. Hartman and Speert gave 5 to 20 mg. of crystalline progesterone daily, for periods ranging from 20 to 32 days, to monkeys castrated respectively 37 days, 50 days, 8½ months, and 4 years.

The hormone produced effects which were in part like those of progesterone following estrogens, and in part like those of estrogens given directly. Reddening of the sex skin, for example, an effect which would have been produced in these monkeys by very small doses of estrone, was produced by progesterone if given in the large dose of 20 mg. daily. Growth of uterus and vagina, and vaginal cornification (all characteristic effects of estrogen) resulted from the treatment. Hormone-deprivation bleeding (experimental menstruation) followed discontinuance of treatment, just as it follows discontinuance of estrogen alone or of the estrogen-progesterone sequence. Development of the mammary gland, with lobular proliferation of the acini, occurred. The authors conclude that the specificity of action of the steroidal hormones is less than has heretofore been supposed.

#### ESTROGENIC HORMONES

Dr. Hartman, with Dr. C. F. Geschickter, of Baltimore, has been treating rhesus monkeys with very large doses of estrogenic hormones over long periods of time. The chief results of these experiments, which were undertaken to study the relation of the ovarian hormones to cancer and other tumors in the monkey, will be reported later. Meanwhile certain collateral results have been described from time to time. Drs. R. Tyslowitz and Hartman have followed the blood-cell count, reticulocyte count, and hemoglobin level in some of these animals. No significant changes were found, nor anything to indicate a toxic effect of the large doses of estrogens.

Dr. Hartman and Dr. Walter Fleischmann, of the Department of Pediatrics of the Johns Hopkins Medical School, have studied the amounts of cholesterol in the blood serum of rhesus monkeys. The matter is of interest because of the similarity in molecular structure between the long-known steroidal substance cholesterol, which is a plentiful constituent of the animal body, and the sex-gland hormones. At present the biological chemists do not know whether there is any functional relationship between these two groups of steroids. Hartman and Fleischmann found an average blood-serum cholesterol level of 120 mg. per cent in normal females at various times of the menstrual cycle, 110 mg. per cent in the first half of pregnancy, and 80 mg. per cent in the latter half of pregnancy. In 7 of the female monkeys mentioned above, which had received very intensive treatment with estrogenic hormones, the serum cholesterol was high, averaging 151 mg. per cent.

Dr. Thomas R. Forbes, of the Department of Anatomy of the Johns Hopkins Medical School, published during the year a full report of his experiments on the absorption of pellets of crystalline hormones. A summary of this work was given in Year Book No. 40.

Several years ago French investigators reported that the administration of one of the estrogenic hormones to rabbits caused, in certain cases, a change in hair

color and loss of hair in symmetrical areas. In guinea pigs and also in human beings treatment with various estrogenic and androgenic hormones had sometimes been followed by changes in skin pigmentation. In his rats which received pellets of ovarian steroid hormones, Dr. Forbes had an opportunity to make similar observations. In albino rats he noticed partial pigmentation of the fur, and in a strain of dark gray-brown rats he observed alopecia (loss of hair). These results followed implantation of pellets of a large series of estrogenic hormones (of both the naturally occurring and the synthetic types) and their esters. Of the androgenic hormones, androsterone was active in this respect but not testosterone dipropionate.

#### REPRODUCTION IN THE MUSKRAT

In connection with the Fish and Wildlife Service of the U. S. Department of the Interior, Dr. Forbes has sought to determine the breeding season of the muskrat. Five hundred and sixty-two animals of both sexes were trapped in Maryland. Sections of the testes and ovaries indicate that in the males spermatogenesis begins about the middle of December and continues until the following October. In the ovaries of the females corpora lutea appeared late in February, and similar evidence of ovulation was found until the end of October.

#### SEX EDUCATION

Our Department is primarily devoted to investigation of fundamental problems, and most of our work is not expected to find immediate application to human welfare. Dealing as we do, however, with embryology and the physiology of reproduction, we are inevitably brought into contact with the human side of these

subjects and see them in the light of our technical experience. It seems our duty to contribute from time to time to the instruction of the public when there is opportunity to do so through proper channels. Such considerations impelled two of the staff to accept an invitation from the American Medical Association to contrib-

ute articles to a series on sex education. Dr. Corner's article, written in collaboration with Dr. C. E. Landis, of New York (bibliographic reference in Year Book No. 40), dealt with sex education of adolescent

boys and girls. Dr. Hartman dealt with information for the woman at menopause. Both articles were widely circulated in *Hygeia*, the Association's magazine for popular medical instruction.

## THE MAMMARY GLAND

### ACTION OF ESTROGENIC HORMONES

While a student and intern at the Johns Hopkins Hospital, Dr. Harold Speert made an extensive study of mammary-gland problems. Many of the animals and notes of Dr. Hartman's monkey colony were put at his disposal for this purpose. Some of the results were mentioned in Year Book No. 40.

One of Dr. Speert's experiments deals with the question as to how the estrogenic hormones act upon the mammary gland to make it grow. Certain experimental work in recent years has suggested the possibility that injected estrogens exert their effects through the pituitary gland. To test this question, Dr. Speert took advantage of the fact that estrogenic hormones are absorbed through the skin. Using immature male rhesus monkeys, he applied estrone in alcoholic solution to the left nipple, and alcohol alone to the right. In three such experiments the left mammary gland grew far more than the right. This result indicates that the action of the hormone was direct rather than through the pituitary gland, for otherwise a similar growth response of the two glands would be expected. It should be noted, however, that the experiment does not exclude the possibility of joint action of pituitary and estrogenic factors, as indicated by recent work of Turner and others.

### CYCLIC CHANGES IN THE MAMMARY GLAND

In a preliminary report Dr. Speert discusses the cyclic changes in the mammary

gland. It has long been known that many women experience a sense of fullness and an increase in the size of the breast in the premenstrual phase of the cycle. Confirmation and analysis of these changes by histological methods have, however, been difficult to secure, because of technical difficulties in collecting and preparing the material. The mammary gland of the rhesus monkey is much easier to study, and the material can be collected under experimental conditions. Dr. Speert subjected 9 monkeys, having regular menstrual cycles, to periodic biopsy of the mammary glands. Whole mounts or spreads of the gland tissue were made as well as sections. He found a definite series of cyclic changes in relation to the cycle. Beginning 7 to 10 days before the onset of the cycle, the lobules begin to enlarge and in some instances the individual acini are dilated. The blood capillaries become engorged. The changes attain their height at about the time of menstruation and slowly regress thereafter. They occur only in ovulatory cycles.

### HYSTERECTOMY AND THE MAMMARY GLAND

There are certain indications, not always clearly defined, and evidently varying from species to species, that the uterus has some sort of influence (presumably endocrine) upon the corpus luteum and the mammary glands. In the guinea pig, for example, it appears that removal of the uterus when there are corpora lutea in the ovary causes persistence of corpora lutea and concomitant growth of the mammary glands.



These effects have not been found in some other species. Dr. Speert observed a monkey from which Dr. Hartman removed the uterus on the 11th day of pregnancy. Biopsies of the mammary gland showed enlargement of the mammary lobules 5 days later, at the time of the expected maximal corpus luteum effect. Subsequent biopsies revealed retrogressive changes during the 6 weeks after operation. In this one case, hysterectomy apparently failed to delay involution of the corpus luteum and had no effect on the mammary glands.

#### SUPERNUMERARY MAMMARY GLANDS AND NIPPLES

In a careful review, Dr. Speert summarizes the literature on supernumerary mammary glands. These are relatively common in the human race, occurring in about 1 per cent of all individuals. Most of these accessory glands or nipples occur somewhere along the milk line, from axilla to groin. Their structure varies from an extremely rudimentary state to that of the typical breast. There is very little information about the condition in lower mammals, and Speert was able to find only eight reports of supernumerary nipples in apes and monkeys. To these he now adds 13 cases observed in approximately 1000 rhesus monkeys which have been studied in the Carnegie colony. Including one case previously reported by Hartman, the frequency of occurrence is about 1.4 per cent, which is within the order of frequency in the human species. In only 5 of these cases was glandular tissue associated with the accessory nipple. Supernumerary nipples were found susceptible to stimulation by local application of estrogenic hormone.

A guinea pig observed by Dr. Speert had an extra pair of accessory nipples. In this species such nipples are exceedingly rare. Single ones have been reported only twice, and an accessory pair only in one previous case.

#### "PALE EPITHELIUM" IN THE MAMMARY GLAND

Pathologists have been interested for many years in certain cells of the mammary gland, usually found lining mammary cysts. Because of their tendency to stain lightly as compared with the usual gland cells, these special cells are called "pale epithelium." They are generally found in the 4th and 5th decades of life. Their origin and their possible relation to cancer of the breast have been much discussed. It is possible that more than one type of cell has been placed in this category. Recently experimenters have noticed the appearance of cells resembling the "pale epithelium" in rabbits and rats which had received long-continued treatment with estrogenic hormones. Speert has now had an opportunity to study in this regard the mammary glands of Hartman and Geschickter's monkeys mentioned above, which received very intensive and long-continued treatment with estrone. In 4 of 8 castrated animals and 1 of 7 intact monkeys thus treated, pale cells developed. They appeared at various times after the 10th week of treatment. They most commonly occurred in solid islets, rather than in cysts as in the human cases. Speert concludes that these cells arise from the mammary epithelium and represent a metaplastic alteration of normal mammary-gland cells. Since none of these animals developed carcinoma, there is no support for any possible relation of the pale cells to the origin of malignant tumors.

## CYTOLOGY

## MYELOMATOUS TUMORS

Dr. Margaret Reed Lewis, of the Department's staff, is at present carrying on her work in the laboratories of the Wistar Institute of Anatomy and Biology in Philadelphia. Working with Dr. G. B. Mider, of the National Cancer Institute, Dr. Lewis has recently been studying certain transmissible tumors of mice. These tumors are produced, as described by Morton and Mider, by first treating mice of a dilute-brown strain by painting them with methylcholanthrene and afterward transplanting bits of the spleen, lymph node, or buffy coat of the blood of these mice into normal mice of the same strain. Myeloid tumors are thus induced. Lewis and Mider now find that such tumors may be transplanted serially into Bagg albino mice, in which they will grow, metastasize, and produce a general disturbance of the host animal just as in mice of the strain of origin (dilute brown). Up to 8 days after implantation the effects are indistinguishable. In the dilute-brown mice, however, the tumors progress until death of the animal, which occurs about the 12th day. In the majority of the Bagg albino mice, the tumors begin to regress after the 8th day, and within a few days the animals regain their normal health and appearance. Such mice are then immune against the growth of another implant of the same kind of tumor, but not to that of a sarcoma from the same or another strain. Here, then, is a very sharply defined, rapidly detectable difference between two strains of animals with respect to susceptibility to tumor growth, which should furnish opportunity for investigation of the biological and chemical factors influencing the growth of tumor grafts.

In another article Drs. Lewis and Mider

discuss the identification of the cells of these tumors. In Year Book No. 39 mention was made of a new way of identifying the cells of the blood-forming organs, introduced by Dr. Lewis, by studying their mode of locomotion and their characteristics of form while moving, in motion pictures of living cells in tissue cultures. When this method was applied to the tumors induced by methylcholanthrene, it was found that their cells resembled those of myeloblasts and differed from lymphoblasts and mononuclear phagocytes. The tumors are therefore properly classified as myelomas. The authors had an opportunity also to study the cells of two cases of spontaneous leukocytosis arising in dilute-brown mice. These cells resembled leucocytes in characteristic form and motion.

## STUDIES ON LIVING SPINAL-GANGLION CELLS

About forty years ago the Strasbourg anatomist Bethe and the great Spanish histologist Ramón y Cajal brought the neurofibrils to the general attention of those interested in the nervous system. These are delicate threadlike strands, which in suitably stained preparations can be seen coursing in every direction through the cytoplasm of the nerve cells and passing from the cell into the axone fiber and the dendrites. Their complexity and sharp definition, as seen in preparations by Cajal's method, have led many neurologists to think of them as the fundamental channels of communication within the nervous system, like the individual wires in a telephone cable. On the other hand, the very existence of the neurofibrils has been denied, on the ground that they can be seen only after elaborate and somewhat drastic chemical treatment of nerve tissue. With the advent of the tissue-culture

method, efforts have been made to see the neurofibrils in living, growing nerve fibers and nerve cells. Some observers have reported seeing them, others have announced their absence.

Dr. Donal P. Murnaghan, who spent the year 1939-1940 in our laboratory as a traveling student of the National University of Ireland, again took up this question. He was able to cultivate cells of the spinal ganglia of chick embryos and newborn mice and to study them while living, under high powers of the microscope. He was able also to visualize by vital staining the mitochondrial granules and "neutral red bodies" of the living cells.

Murnaghan finds that neurofibrils are not visible in normal living cells in such cultures. Only when cells are suffering damage do fibrillar appearances become visible in the cytoplasm. He suggests that possibly there is something existent but invisible which becomes apparent in the moribund or nonliving cell under suitable conditions. He thinks that observers who have seen appearances resembling neurofibrils in living cells have been deceived by seeing the alignment of the mitochondria. The article is illustrated with very fine photographs of the living ganglion cells, made by Mr. Reather from Dr. Murnaghan's preparations.

## THYROID AND ADRENAL GLANDS

### ENZYME ACTIVITY OF THE COLLOID OF THE THYROID GLAND

One of the oldest enigmas of histology has to do with the thyroid gland. This organ is composed of rounded chambers or follicles. Behind the cellular walls of each of the follicles lies a network of blood vessels. From these vessels the cells of the follicles receive the ingredients from which they elaborate a secretion in the form of a thick fluid (colloid), which is then stored in the cavity of the follicle. When needed by the body the colloidal material or its active ingredients must obviously be reabsorbed, back through the follicle lining into the blood stream. A major ingredient of the colloid is a protein of large molecular size, thyroglobulin; just how such material can pass through living tissue with apparent readiness becomes a question. It has been suggested, and indeed actually demonstrated, that extracts of the thyroid gland contain a proteolytic enzyme which might catalyze the formation and the hydrolysis of thyroglobulin, so that the passage both ways through the follicular wall would be effected by

smaller molecular masses, which would afterward go in to be built up into thyroglobulin or come out from its hydrolytic breakdown.

Dr. Eduardo de Robertis, of Buenos Aires, while working with Dr. Gersh in the Anatomical Laboratory of the Johns Hopkins Medical School on a Rockefeller fellowship, obtained further evidence concerning this question. He was able, by using microdissection pipettes, to withdraw droplets of colloid from individual follicles of anesthetized rats. Such droplets, placed on gelatine plates under proper conditions, were able to digest the gelatine. This demonstrates the existence of proteolytic ferment actually in the colloid. The colloid is an optically homogeneous viscous fluid, of slightly acid reaction (pH 6.6). After the administration of pituitary thyreotropic hormone or of potassium iodide it becomes less viscous; but after a longer period of iodine administration the viscosity increases. The proteolytic enzyme gains activity in the acid range and loses it in the alkaline. Within the physiological pH range the activity increases after ad-

ministration of thyreotropic hormone and also temporarily after potassium iodide. The observations strongly support the hypothesis that an enzymatic mechanism is involved in the hydrolysis of the colloid protein and subsequent reabsorption of the products of hydrolysis.

#### BLOOD VESSELS OF THE ADRENAL GLAND

The isolation of hormones from the cortex of the adrenal gland has caused renewed interest in the anatomical structure of this gland and particularly in its blood vessels. The classic description of the vessels of the dog's adrenal, published 42 years ago by the late J. M. Flint, is limited to one species, and of course does not take into account modifications due to physiological states. Dr. I. Gersh, of the Department of Anatomy of the Johns Hopkins Medical School, and Dr. Arthur Grollman, formerly of the Department of Pharmacology, have studied the mouse and rat, using not only normal infant and adult animals, but also mice stimulated by low temperature and by thyroid extract to produce hypertrophy. They give a thorough and detailed account of the blood

circulation in the adrenal glands of these animals as it varies with age and condition. The most important point in their work is the demonstration that capillaries exist in the adrenal medulla (a fact which has been controverted so far as the mouse is concerned). The circulation through the cortex and that through the medulla seem to be distinct except that the blood from both drains into the medullary veins. This is an important matter because some have thought that the blood from the cortex passes through the capillaries of the medulla and can influence its function.

The vessels of the X zone, which is peculiar to the mouse, are found to be loose-meshed, with few anastomoses. As would be expected, the capillary network becomes much richer when the X zone is made hypertrophic by experimental stimulation. Attention is called to the alteration of the capillaries of the fascicular zone from the irregular capillary bed seen in the embryo and in small accessory glands to the elaborately parallel pattern of the mature gland, and an explanation of the final arrangement on the basis of physiological need is offered.

#### GROSS AND COMPARATIVE ANATOMY

The group of comparative anatomists in the Department of Anatomy of the Johns Hopkins Medical School, closely associated with the Carnegie Department of Embryology, has contributed this year a number of important articles on the anatomy of man, the other primates, and the vertebrates in general.

##### THE FEMORAL TROCHANTERS

Mr. A. Brazier Howell has discussed the homologies of the large bony processes or trochanters which characterize the head of the thighbone. There has been great difficulty in correlating the trochanters of

the various tetrapod vertebrates. Howell considers them from the standpoint of myology; that is to say, he regards the trochanters as associated with the attachment of muscle groups. The problem of correlating them thus becomes largely one of correlating homologous muscles. Howell concludes that, in summary, the mammalian lesser trochanter is a femoral group or iliopsoas process. The greater trochanter is a deep gluteal or partly peroneal group process with associated short flexor, chiefly tibial, elements around its margin and a superficial gluteal element either included or separate, in the latter case

sometimes causing a third trochanter. The adductor tubercle is the fourth trochanter of mammals. An adductor process also occurs in some marsupials.

The internal trochanter of *Iguana* is essentially a short flexor, largely tibial, and a deep gluteal or peroneal process. The faint process situated more laterally (dorsally), or external trochanter, is a femoral or probably iliacus process. The fourth trochanter of some fossil reptiles is probably a caudofemoral process.

In modern birds, the large lateral trochanter represents a fusion of the elements of the mammalian greater and lesser trochanters, but without the element (superficial gluteal) of the mammalian third trochanter and with, in the fowl, the element of the fourth trochanter. When the last is well defined it is a caudofemoral process.

#### THE SHOULDER OF THE ARMADILLO

Dr. Samuel S. Miles,<sup>1</sup> working at the suggestion of Mr. Howell, has described very fully the shoulder musculature of the nine-banded armadillo of Texas, *Dasypus novemcinctus texanus*. The matter is of interest because the skeleton and muscles of the shoulder in this animal are highly adapted to the act of digging. The shoulder joint permits movement in the front-and-back direction much more amply than rotation or abduction. The scapula and humerus are formed in such a way as to allow strong attachments of the muscles giving leverage in the antero-posterior plane, and bringing about retraction of the manus. For details of the musculature Dr. Miles' paper must be consulted.

<sup>1</sup>The author of this competent study was killed in action in the South Pacific area, August 1942, while serving as medical officer of the U. S. Navy, attached to the Marine Corps.

#### A NEW FASCIA OF THE HUMAN BODY

The adult human body has been so thoroughly studied for hundreds of years, by anatomists prepared to detect the least novelty, that it is rare nowadays to have a new structure described. Dr. Ferdinand C. Lee, however, has called attention to a hitherto undescribed fascia situated between the serratus anterior muscle and the chest wall.

It was present to a greater or less degree in every one of the thirty bodies that were examined, being more evident in thin individuals, and being thickest near the inferior angle of the scapula. Microscopically, it is composed of connective-tissue fibers with a substantial interlacing of elastic tissue. The fascia, although present in a young chimpanzee, was absent in the ordinary laboratory animals. The function of the fascia is probably to provide a protective surface for the motion of the scapula.

#### THE HOMOLOGIES OF THE FOREARM FLEXORS

Probably no part of the body has been adapted, during the course of animal evolution, to as many different functional uses as the fore limb. For this reason its comparative anatomy, and especially the anatomy of its muscles, has been the object of much study and discussion. Dr. William L. Straus, Jr., who recently published an elaborate analysis of the extensor muscles of the forearm, now presents a study of the forearm flexors in urodele amphibians, reptiles, and mammals. The results, which trace in detail the development of the individual muscles from their original matrices or common muscle masses, cannot be summarized instructively here for the nonspecialist reader. The most interesting general point is that very few distinctively new muscles have been differentiated in the evolution of

reptiles and mammals; those present in these higher tetrapods can usually be recognized, partially or fully differentiated, amid the muscle groups of the amphibians.

#### THE LOCOMOTION OF GIBBONS

The question of the way in which the apes use their hands in walking was discussed in last year's report (Year Book No. 40) in connection with the studies of Dr. William L. Straus, Jr. It was pointed out that the gibbons, unlike the great apes, are able to extend their fingers when the palm of the hand is on the ground, so that they can assume the palmigrade position when walking. The great apes, on the other hand, must walk on their knuckles, because they cannot extend their fingers when in walking position. To what extent the gibbons actually utilize their adaptability to the palmigrade position has been questioned by Dr. Aleš Hrdlička, who reports gibbons that walked on their knuckles. Dr. Straus, in an interesting note, cites new evidence collected in the field by Dr. C. R. Carpenter. This shows that the mode of walking varies a good deal. The palmigrade pattern is among those actually used. An infant gibbon observed by Dr. S. L. Washburn also frequently placed its hands flat when walking. The present conclusion is that although adult gibbons seldom actually use the forearms for support when walking, when they do, they sometimes walk on their palms, thus retaining a capacity that has been lost by the great anthropoid apes.

#### RELATIVE CRANIAL CAPACITY IN PRIMATES.

The cranial capacity, i.e. the volume of the cranial cavity, furnishes a close indication of the size of the brain, and is therefore from the anatomist's standpoint one of the outstanding characteristics of a race

of mankind or an animal species. In general, the larger the animal species, the smaller the relative size of the brain in proportion to the rest of the body. In any individual, moreover, the brain is relatively larger at birth than afterward.

There has been a dearth of reliable information about the relation between body weight and cranial capacity in the primates. In the case of many species, the number of specimens known to be normal and fully grown is small. Dr. Adolf H. Schultz, as part of his program of study of the physical characteristics and growth of the primates, has compiled the data on relative cranial capacity for 385 specimens of various species from marmoset to man. The marmosets rank lowest with respect to relative cranial capacity, followed in ascending order by the night monkeys (*Aotus*) and the howler monkeys (*Alouatta*) and then by capuchin monkeys, macaques, guenons, langurs, and proboscis monkeys. The spider monkeys and gibbons come next. All three great apes (chimpanzee, gorilla, orang) fit one curve which lies still higher on the scale, and the relative cranial capacity of man is at all ages far greater than that of any other primate. Dr. Schultz has been able to calculate the probable relative cranial capacity of the fossil man *Sinanthropus* (Peking man) and finds that it must have been nearer to that of recent man than to that of any great ape of similar body weight.

#### OBSERVATIONS ON A GORILLA AND AN ORANG

Through the cooperation of Dr. J. F. Fulton, of Yale University, Dr. Schultz has had an opportunity to make morphological observations on two adult female great apes of closely known age, the gorilla "Janet," formerly of the Bronx Zoo and more lately in the Yale colony, about 13

years and 3 months old at the time of death, and the orang "Lulu," which was in the Yale colony from 1932 until her death in 1941 at about 11 years and 4 months. Such dated specimens of the great apes are rare indeed. The description deals with many details, and a summary is difficult. Taking what he has learned from these two animals into consideration along with other evidence, Dr. Schultz concludes that (1) the three great apes reach adulthood at practically identical ages; (2) the permanent dentition is normally completed in the eleventh year; (3) growth in general ceases, as a rule, between the ages of 10 and 12 years; (4) the last happenings in skeletal development are the obliteration of most of the cranial sutures, the complete union of the clavicular epiphysis, and the final fusion of the bony rims at the iliac crest and at the lower angle of the shoulderblade. All this occurs generally between the ages of 12 and 14 years. In all probability rules 2, 3, and 4 apply equally to chimpanzee, gorilla, and orang. In man, as is well known, these phases of maturation take place at very much more advanced ages. This fact must be regarded as a profound, though perhaps comparatively recent, evolutionary specialization of man, which is unique among primates.

The paper is illustrated with two skillful portraits of "Janet" from the pen of the author.

#### GROWTH AND DEVELOPMENT OF THE PROBOSCIS MONKEY

As a participant in the Asiatic Primate Expedition of 1937, organized by Mr. H. J. Coolidge, Jr., Dr. Schultz was able to collect 51 specimens of the proboscis monkey, *Nasalis larvatus*. A few other specimens have also been available to him. His meas-

urements are recorded in a comprehensive paper which is an archive of data to be used later when the time comes for a general comparison of bodily proportions and growth in the primates.

Included among the illustrations are three handsome plates by the late celebrated medical illustrator Max Broedel, illustrating the facial appearance of this strange creature.

#### GROWTH AND DEVELOPMENT OF THE ORANGUTAN

In volume XXIX of the Carnegie "Contributions to Embryology" appears an extensive monograph by Dr. Schultz on growth and development of the orangutan. This article sums up the work of many years. It has been compiled from a large number of specimens from various sources, including the Asiatic Primate Expedition of 1937, several museums, and other collections. Dr. Schultz has made a very large series of measurements and other morphological observations, from mid-fetal life to old age. The results provide a mine of information which will be of great use in formulating the laws of growth and bodily proportions in primates. The summary alone comprises 3½ pages of facts, and we can do no more here than cite a few items.

Prenatal growth lasts 39 weeks. Postnatal growth appears to be completed sometime between the ages of 10 and 12 years. The males grow to be much larger than the females, which average only 49 per cent of the weight of the males (adult human females average about 81 per cent of the adult male weight). Female orangutans, like humans, can become pregnant long before their second dentition is complete. The order of eruption of the teeth resembles that in the chimpanzee, differ-

ing in many respects from that in man. Developmental anomalies of the permanent teeth and dental disease are very common. Disturbances of the growth of the skeleton are also very common in wild orangutans, and all sorts of disease conditions are evident in the skeleton, including healed fractures, sinus infections, and arthritic joints. About one-third of all adult wild orangutans have had broken bones.

It is as yet impossible to compare in detail the conditions of growth and development in orangutans with the corresponding conditions in many other primates. It can be concluded, however, that in general the ontogenetic processes of orangutan and chimpanzee are far more similar to each other than those of either of these species are to those of man.

The interesting and valuable collection of pen drawings of heads of primates which have accumulated in the course of Dr. Schultz' studies is augmented in this article by three notable portraits drawn by the author, illustrating respectively an infant orangutan, an adult female, and an adult male.

#### RELATIVE GROWTH OF LIMBS AND TAIL IN MACAQUE

From an investigation on the anthropoid apes, Dr. Hyman Lumer, of Fenn College, pointed out a few years ago that the relative growth of the limb bones conforms to the law  $y = bx^a$ , in which  $x$  and  $y$  represent two parts of the body and  $b$  and  $a$  are constants. Thus the plot of length of forearm, for example, against trunk length results in an exponential curve, and if these measurements are plotted logarithmically a straight line results.

From the data accumulated by Dr.

Schultz, Dr. Lumer and he now study in the same way the growth of the limb segments and tail in several species of macaque. A striking point which comes out at once is that in the rhesus monkey, for which the investigators had fetal as well as postnatal material, there is a break in each of the relative growth curves they plotted, at a value of  $x$  corresponding roughly to the time of birth.

Another point will be of great interest to those who are concerned with the difficult matter of the classification of monkeys. Bodily proportions are of course constantly used in distinguishing between closely related species. All the taxonomists have used the relative length of the tail, for example, as one of the means of distinguishing between the rhesus and the Java macaques. Relative growth curves like those of Lumer and Schultz not only are more precise than mere measurement of individuals, but also take growth into consideration and thus utilize relative proportions at various ages, not in adults only. Curves thus obtained for the relative growth of the tail are different for each of six species studied, except that the point for *Macaca irus*, of which adults only were available, falls practically on the curve for *M. sinicus*. The authors thus tentatively conclude that the genus *Macaca* does not constitute a single tribe, but is divisible into several groups. The five tribes which they are thus able to demarcate correspond for the most part to the subgenera of the macaques set up by Elliot in his *Review of the primates* on the basis of conventional taxonomic methods. The authors suggest that their method, if it could be applied to a large number of specimens, might well yield valid taxonomic categories and thus improve the groupings determined by naturalists on the basis of crude comparisons of bodily proportions.



## THE NERVOUS SYSTEM

## ISOLATION OF PART OF THE SPINAL CORD

Some years ago Dr. Sarah Tower found it possible to isolate a part of the spinal cord from incoming impulses, by transverse section at two levels and severance of the sensory roots between. These experiments, which were done on dogs, have now been confirmed in monkeys by Dr. Tower, with Drs. David Bodian and Howard Howe, all of the Department of Anatomy of the Johns Hopkins Medical School. In two out of three cases the isolated lumbosacral cord survived the experimental trauma. By suitable staining, the investigators obtained a picture of the intrinsic and motor mechanism of the cord, cleared of posterior root fibers and descending fibers. The reactions of the animals have confirmed the conclusion reached after similar study of isolated segments in dogs, that the mammalian cord mechanism operates only under the stimulus of arriving nerve impulses. Deprived of such excitation, the cord produces no activity which reaches effectiveness in the skeletal musculature.

## FIBRILLATION IN INACTIVATED MUSCLE

When a muscle is deprived of its nerve supply by cutting of the nerve, it atrophies. To this well known fact Dr. Tower added three years ago the new observation that such a muscle undergoes ceaseless minute contractions of its fibers or parts of the fibers, a process called technically fibrillation, and continues in this peculiar state of activity for months, until atrophy sets in. The question now arises whether muscles made inactive by isolation of that part of the spinal cord by which they are supplied with motor fibers also undergo fibrillation. In a monkey with isolated surviving lumbosacral cord, the right sciatic nerve was cut. Muscles of the right thigh were therefore denervated, while those of the left thigh were inactivated without denervation. The former were found to fibrillate, the latter not. Atrophy developing under conditions of inaction without denervation may therefore be considered inactivation atrophy, or atrophy of disuse.

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## DEPARTMENT OF GENETICS

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M. DEMEREC, *Acting Director*

The first annual report of the present Acting Director may be an appropriate place for a short survey of the problems covered by the work of the Department of Genetics. The Department was organized almost forty years ago (1904), when the science of genetics was in its early infancy—was, in fact, still an unnamed child, with another two years to wait before acquiring its present name. In 1902, when the Carnegie Institution was incorporated, interest in the new science of heredity was running high; therefore, it is not at all surprising that the Trustees took under consideration the establishment of a laboratory where work in the new field could be carried on. The first report of the Advisory Committee on Zoölogy includes the following statement: "As regards an experimental station, among the most important desiderata at present are experiments in heredity, in variation, in instincts, in modification, all of which should extend over a series of years and be planned systematically" (Year Book No. 1 [1902], p. 167). In addition, this first issue of the Year Book contains two memoranda written by prominent young biologists regarding plans for an experimental station for the study of heredity. One of these plans was accepted, and its author, Dr. C. B. Davenport, was appointed to take charge of the new laboratory.

It was realized at the time the laboratory was founded that heredity furnishes a valuable clue to an understanding of the mechanisms of organic evolution. Accordingly, the name "Station for Experimental Evolution" was given to the new division of the Institution. The young sci-

ence of genetics was not ready, however, for an immediate attack on the problem of evolution. The phenomena of heredity constitute one of the most important attributes of living matter; and heredity may and should be investigated as a fundamental physiological function, regardless of its bearing on organic evolution. Moreover, so far as the evolutionary implications of genetics are concerned, it took almost forty years to forge the concepts, experimental techniques, and quantitative methods with the aid of which a scientifically rigorous study of evolutionary changes could be undertaken. Finally, the heredity of man presents problems that require still different methods for their solution, although it is becoming more and more evident that this study is a part of the larger field of evolutionary genetics. Shortly after the Eugenics Record Office was taken over by the Institution, the two laboratories were combined (1921) under the title Department of Genetics.

Although the Station was organized by a zoologist, one of its first three staff members was a botanist. Thus, from the very beginning the work of the laboratory was arranged so as to break down the conventional dividing lines between sciences, and the new problems were attacked by the concentrated effort of representatives of several branches of science. This approach was, in a way, prophetic, for the present stage in the development of biology is characterized by a trend away from specialization and toward a closer integration of biological disciplines. Such an attitude toward research is still one of the outstanding characteristics of this Department.

From the time the laboratory was organized, the work with plants and that with animals have been carried on concurrently. When it soon became evident that for the solution of certain fundamental problems the help of a chemist was essential, a chemist was added to the staff (1909); and when, later on, the problems under consideration branched out into the related field of physics, physical equipment was procured and the cooperation of physicists was enlisted. From its early days, problems of human heredity were included in the research program of this Department, and some of the most important pioneering studies in that field were carried on here. The interests of the laboratory soon expanded far beyond its facilities, and as a consequence it has always cooperated with other institutions in research on problems where such cooperation was advantageous. Cooperative work has increased with the growth of the Department, and today constitutes an important part of its activity.

The Carnegie Institution's interest in research on problems related to genetics did not stop with the establishment of this Department. A glance through the reports published in the Year Books will show that the research of many scientists working in this field has been furthered by the Institution's support. The list of Research Associates contains the names of W. E. Castle, E. B. Wilson, T. H. Morgan, C. B. Bridges, A. H. Sturtevant, C. E. McClung, R. Pearl, H. E. Crampton, E. B. Babcock, H. D. Goodale, L. R. Dice, F. B. Sumner, Th. Dobzhansky, and J. Schultz. A particularly strong measure of support was provided during those early days when genetics was in special need of recognition and assistance. This backing given to genetical research by the Institution undoubtedly accounts to a large degree for the fact

that the United States now occupies a leading position in this branch of science.

All along the line, this Department has made significant contributions toward the solution of current problems in genetics. Davenport's early work with poultry, canaries, and sheep, as well as on the inheritance of eye color and other characters in man, furnished classic examples of Mendelian inheritance; the work of G. H. Shull with *Oenothera*, *Capsella*, and *Melandrium*, and particularly with maize, contributed fundamental knowledge which has greatly improved the methods of plant breeding; the pioneering research of C. C. Little opened up a road for experimental studies of the inheritance of cancer; and the brilliant work of the late John Belling laid the foundation for cytogenetics, and made possible the unique cytogenetic research carried on with *Datura* by Blakeslee and his group. MacDowell's studies of embryonic growth in mice, and MacDowell and Potter's studies of leukemia in mice, are but two examples of painstakingly thorough research which has contributed much toward an understanding of these problems. New vistas in the endocrine field have been opened up, and better understanding of the relation between endocrines and heredity has been achieved, through the work of Riddle and his associates. C. W. Metz' studies with *Sciara* focused attention on a hereditary mechanism strikingly different from those usually found in other organisms; and the cytological research of Kaufmann, as well as the genetical and cytological work carried on by the gene group, has extended the sum of knowledge concerning the nature and action of genes. The statistical studies of the late Arthur J. Harris made a significant contribution to biometry; the work of A. M. Banta with *Cladocera* clarified the question of germinal and somatic variations in parthenogenetic animals; and

the studies of Davenport and Steggerda have made an important contribution to our knowledge of growth in man.

The development of genetics has been exceptionally rapid. At present, genetics is only a little more than forty years old—very young for a scientific discipline. But discoveries and spectacular events in this field follow each other in such rapid succession that textbooks and reviews published only a few years ago are now hopelessly outdated. New problems and new lines of approach are being discovered at a rate higher than that of the solution of the classic problems. With the passing of infancy and the onset of maturity of the science, the research methods used by geneticists are undergoing a rapid change. From the simple biological methods employed at first, the experimental technique has evolved into a complex structure requiring the use of optical, physical, and chemical instruments. From the purely biological science of early days, genetics has developed into a science where cooperation with physics, chemistry, and mathematics is essential.

One of the three fundamental groups of problems facing modern genetics today relates to the mechanism whereby hereditary characteristics are transmitted from parents to offspring. What is the chemical and physical structure of genes? how do they reproduce? how do changes in genes occur? what is the relation between genes and chromosomes?—these are but a few of the questions still waiting to be answered. These problems are being intensively studied at the Department, in cooperation with workers in a number of other institutions—particularly with Dr. A. Hollaender, biophysicist at the National Institute of Health, Bethesda, Maryland, and with a number of physics laboratories in New York City.

The second cycle of problems concerns

the action of genes in development. Why does a single cell, a fertilized ovum, develop into a complex organism, and how do the genes and chromosomes exert their determining influence on this process? Numerous attempts have been made to solve these problems, but so far all have failed for lack of fundamental information and reliable methods of approach. The work of MacDowell and Potter and of Riddle and his group is contributing this essential information.

The third cycle of problems involves the processes of change within groups of organisms (populations), which in a broad sense might be called organic evolution. It required almost forty years for genetics to accumulate information needed for work on this problem, and today the basic methods for the work are available. The Department, as now organized, is participating in research on this problem, in close collaboration with Professor Th. Dobzhansky, of Columbia University, who is a Research Associate of the Institution.

The field covered by genetics is so wide that research can most effectively be carried out through cooperation and close contact between various research groups. The location of this Department is admirably suited to such cooperative arrangements. It is situated almost in the suburbs of New York, where there are numerous research establishments, and this enables the staff of the Department to participate in the scientific life of that city. At the same time it is sufficiently secluded to be attractive to scientists connected with universities and colleges as a place to spend their vacations in congenial work. The Department has regularly a number of such summer guests, who furnish a stimulus to our research program. Two years ago, a closer collaboration was established with the neighboring Biological Laboratory of the Long Island Biological Asso-

ciation, and thus the opportunities for summer research have been greatly enlarged. Through the Symposia on Quantitative Biology, held yearly at the Biological Laboratory, we are now able to utilize a well established international conference for the discussion of problems in which our Department is interested.

The past year has brought about significant changes in the Department. At the end of November 1941, its second director, Dr. A. F. Blakeslee, reached the retirement age and relinquished his post after twenty-six years of distinguished service as staff member, assistant director, and director. During this time Blakeslee enjoyed unequalled opportunities for research, which he utilized to the fullest extent. Under his leadership, genetical work with *Datura* has been developed, and outstanding discoveries have been made in many fields of genetics and cytogenetics. Blakeslee and his co-workers remained with us until September 1942; he then transferred to Smith College, where he will be William Allan Neilson Research Professor of Botany and continue with his investigations as a Research Associate of the Carnegie Institution.

During the past year the Department has been fortunate in having as a guest investigator Dr. Barbara McClintock, a well known research worker on the cytogenetics of maize. Her stay here has invigorated our research program.

As a result of close collaboration with the Biological Laboratory, a number of geneticists worked here during the summer of 1942, making use of the facilities of the Laboratory and the advantages that our Department has to offer. In June a ten-day symposium on "The Relation of Hormones to Development" was held at the Biological Laboratory and was attended by over a hundred scientists. The program of this international conference

was closely related to the work of the Department, and our members derived profit and stimulus from these meetings.

A brief summary will be given here of the individual reports of the various research groups for the year ending September 1, 1942; the reports in full are printed on the succeeding pages.

Nearly six years of study of the role of hormones in the regulation of the maternal instinct in rats has been concluded and the results have been analyzed and published by Riddle, Lahr, and Bates. During embryonic life the hormones of the anterior pituitary gland influence the growth and development of the sensorimotor mechanisms which are later capable of stimulation to sex drive or to maternal drive. In later stages of life the pituitary hormones have been found to provide the sequence of stimuli that results in unlearned maternal behavior. The sex drive, or its unexpressed foundations, is apparently a necessary precursor of the maternal instinct; and thus pituitary gonadotrophins play a part in the origin of the latter instinct, although their output is inhibited temporarily by the agencies that induce maternal behavior. Interrelations among hormones are such that, directly or indirectly and under suitable conditions, several of them promote the exhibition of the maternal drive; but the study produced much evidence that this instinct, which is the last to arise in the life cycle, is provoked primarily by prolactin.

A type of prenatal loss that becomes selective for a given mutation only under certain conditions has been found by the group studying mouse genetics. Mice carrying the screw-tail mutation reach birth as successfully as normals when the prenatal loss of normals is low, but as this increases the proportional loss of screw-tails is progressively greater. This may provide an

explanation of other defective ratios or irregular results.

An excellent illustration of the manner in which a mutation can provide an interpretation of normal developmental processes has been found in the case of the sternum of the screw-tail mouse, which is unique in lacking all signs of division into sternebrae. The conditions associated with the absence of segmentation of the sternum have provided a clue to the conditions responsible for its presence. At the end of each rib a center of new growth is established in the early sternal material. In screw-tails the right and left members of a pair of these growth centers are so far apart that a continuous longitudinal band of fully matured cartilage runs the length of the sternum, before the first deposition of bone. In normals the right and left pairs of these growth centers are so close together that they join, so that immature cells from one side meet immature cells from the other side, and divide the fully mature cartilage into a series of separate masses. This difference determines the presence or absence of segmentation, for bone can be deposited only in fully matured cartilage.

During the past year the gene group worked on a number of problems in which X rays, neutrons, ultraviolet and near infrared rays, and chemicals were used to induce changes in genes and chromosomes and these changes were studied by genetical and cytological methods. The members of the group collaborated with Drs. A. Hollaender and P. A. Cole, of the National Institute of Health, Bethesda, Maryland, and with Dr. I. Gersh, of Johns Hopkins University, in experiments with ultraviolet and infrared radiation; with Dr. S. Zamenhof, New York, in experiments with deuterium; and with the Columbia University cyclotron group, under the di-

rection of Dr. J. R. Dunning, in experiments with neutrons.

Over a period of eight years, data have been accumulating on the correlation between genetic loci and the bands visible on salivary-gland chromosomes of *Drosophila*. This material has been summarized by Demerec and Sutton, and the positions of 44 loci determined. In several instances, the position has been localized to a region covering only one band. Demerec has found a gene in the wild-type Swedish-b stock which increases the mutability of other genes. In collaboration with Zamenhof, he has made an unsuccessful attempt to induce mutations with deuterium. Fano has completed the analysis of an interesting gene which when present in a female prevents hatching of about 80 per cent of the eggs laid by that female.

The preliminary studies of Kaufmann, in collaboration with Hollaender, on the combined effects of X rays with the near infrared or ultraviolet radiation promise to furnish valuable data concerning the factors involved in chromosome breakage and recombination. The high degree of breakage and the great complexity of recombination that may follow such treatment of *Drosophila* sperm is revealed in a rearrangement involving at least 32 points of breakage.

The production by neutrons of dominant and recessive lethals is the object of an extensive new experiment being carried on by Fano. Previous reports, indicating that recoil protons have a good chance of producing more than one recessive lethal at a point where they hit, have not been confirmed. Neutrons seem to be more efficient than X rays in producing lethals connected with chromosomal breaks; but they are less efficient in producing isolated recessive lethals appearing as gene mutations. This situation is contrary to the one



observed in ultraviolet experiments with both *Drosophila* and *Neurospora*, which show a lowered rate of chromosomal breaks as compared with gene mutations.

Demerec, Hollaender, Houlahan, and Sansome undertook a comparative study of genetic effects produced on the fungus *Neurospora* by ultraviolet and X rays. Of the six wave lengths between 2280 and 2967 Å that were used, 2650 Å was found to be most effective in producing mutations. It is of interest to note that nucleic acid has maximum absorption in this region of the spectrum. In the case of X rays, the frequency of mutations increased with the dosage applied; in the case of ultraviolet radiation, the mutation rate increased up to a certain point and then decreased. The "semilethal" type of mutant has been found very frequently among the changes produced by ultraviolet treatments, but has occurred rarely among the X-ray-induced mutants. The meaning of the observed differences between ultraviolet-treated and X-rayed material is being investigated.

Brehme has completed the revision of the manuscript of the late Calvin B. Bridges on "The mutants of *Drosophila melanogaster*," and has prepared it for publication.

It has been known for a number of years that chromosomes may be broken by X rays, by a mechanical pull, or by some undetermined force. It has been known also that broken ends may fuse, thus producing various chromosomal aberrations, such as translocations, inversions, and deficiencies. Notwithstanding many efforts to discover them, however, the basic processes responsible for the breakage-fusion event were not understood. Particularly puzzling was the question whether fusion occurs immediately after a chromosome is broken or whether a broken end may remain "unsaturated." A convincing answer to this question has been obtained

by McClintock. She verified the unsaturated state of a recently broken end of a chromosome, when two nuclei, each of which had a chromosome with a broken end, were allowed to merge, and it was found that the two broken ends, derived from separate nuclei, could fuse. Similarly, she observed that when two recently broken ends enter a dividing nucleus, fusion may occur between these broken ends. When three recently broken ends are present in a nucleus, fusion may occur between two of the three ends. The third end "heals"; it permanently loses its unsaturated state, that is, its ability to fuse with any unsaturated broken end. McClintock likewise determined that even when two unsaturated broken ends are present in a nucleus, healing may sometimes occur before union of the broken ends has taken place. Following this healing, no fusions occur.

Continued investigation by McClintock of the action of a progressive series of homozygous deficiencies of terminal segments of the short arm of chromosome 9 of maize have shown that deficiencies up to and including the terminal third of this arm have very little effect on pollen development. Pollen grains with terminal deficiencies of a chromomere or less are completely functional. Those with longer deficiencies do not function. All the deficiencies studied can give viable and functional embryo sacs and eggs. Endosperms that are homozygous for small terminal deficiencies are normal. The seedlings, however, are modified: pale-yellow seedlings occur when the homozygous deficiency is short, and white seedlings occur when it is slightly longer. The genetic behavior of these deficiency mutants is typically Mendelian. They are allelic, and dominance is an expression of the extent of the deficiency. A slightly longer homozygous deficiency causes early death of the

embryo. The effects on endosperms of deficiencies longer than a terminal chromomere were studied by means of the variegation method, utilizing the behavior of recently broken chromosomes. Endosperm development may be completely normal when a homozygous deficiency of two terminal chromomeres is present. Beyond this region, only patches of homozygous deficient cells, surrounded by normal cells, will develop. As the homozygous deficiency becomes progressively longer, the rate of development, the color of the aleurone, and the starch formation are progressively reduced except for the layer of cells immediately adjacent to normal cells. The cells in this layer appear to develop normally. This suggests that some diffusible substance or substances necessary for development are not produced by the homozygous deficient cells, but may be supplied by normally developing cells. The phenotypic effects of such large homozygous deficiencies are relatively mild. This could be understood if maize were a derived polyploid.

Certain fundamental principles established in genetics can be applied directly to a number of problems met in breeding work with plants and animals. As a consequence of the emergency created by the war, the Bureau of Plant Industry of the U. S. Department of Agriculture acquired a large number of new plant-breeding projects which require a quick solution. In order to facilitate the work, parts of this new load were assigned to various laboratories competent to handle them. Our Department was very glad to cooperate with the Bureau, and has taken up, through Warmke, several projects which it is well equipped to handle. These include an attempt to produce a strain of fiber hemp with greatly reduced marihuana content, and a cytogenetic analysis of the rubber-producing Russian dandelion.

Warmke finds a wide variation in the drug content of individual hemp plants. This is encouraging as a starting point for selection and breeding experiments. The Russian dandelion is shown to be self-sterile and a basic diploid with normal sexual reproduction.

Working with *Datura*, Bergner has continued her analysis of chromosomal changes that have occurred in the evolution of that species; and Satina has made progress in her analysis of the developmental history of the various organs and the contributions of the three germ layers by means of periclinal chimeras. Avery has completed the tests on mutation rate in 22- and 39-year-old seeds which had been stored under especially favorable conditions. He found that the rate is not so high in the old seed as in 10-year-old seed stored in the laboratory.

Steggerda has continued with research in anthropology and human genetics. By comparing the measurements made on Navajo and Dutch children last year with those made in 1931-1934, he found a significant trend toward increase in weight and height among the children of today as compared with children of the same age group seven to ten years ago. A similar trend has been observed by several scientists, but this is the first time that measurements have been made by the same person using a similar technique. Steggerda has completed the analysis of data involving measurements of 100 Negro men from Tuskegee Institute, and compared them with a similar set of data supplied by Professor H. H. Plough on white college students from Amherst. Although the weight for the two groups is approximately the same, the Negro students are about one inch shorter. This is entirely accounted for by the shorter trunk of the Negroes, who also have broader shoulders

and longer arms than the Amherst students.

In order to compare anthropometric technique as used by various scientists, Steggerda had twenty-one investigators measure the same subject. The results of these measurements show considerable variation. These data constitute a starting

point for the standardization of anthropometric technique. At the request of the Smithsonian Institution, Steggerda is making a survey of the known anthropometry of South American Indians. This study now includes data on more than 80 tribes, and covers the material contributed by 132 investigations.

## DATURA STUDIES

A. F. BLAKESLEE, A. G. AVERY, A. D. BERGNER, AND S. SATINA

### EVOLUTION OF CHROMOSOMES IN NATURE

Dr. Bergner has continued her analysis of the gross chromosomal changes that have occurred in the evolution of the herbaceous *Datura* species. In the past fourteen years it has been customary to study and to carry along concurrently many different cytological problems. This procedure has been necessitated by the fact that one obtains commonly only two generations per year. During the past year a few of those problems which were nearest completion were selected for completion if possible by the end of this year.

Whenever necessary, technical "speed-ups" have been used. For instance, in order to determine the modified chromosomes of prime type 96, tester races were crossed to heterozygous PT 96, since the latter has not yet been obtained in the homozygous condition. This necessitated looking at twice as many hybrids, since only a half of the gametes carried the modified PT 96 chromosomes, but a year of time was saved. Also, in the cross of a heterozygous interchange from *D. pruinosa* to *D. ferox* and to *D. discolor* and in *intra se* crosses of *D. metel*, the usual dormant period of seeds was eliminated by peeling off the outer seed coat of seeds as soon as they ripened, breaking the inner seed coat, and planting them immediately in soil. This process, although tedious and

time-consuming, shortened the generation by two months.

In the 1941 annual report, one of the natural prime types of *D. stramonium* (PT 96) could not be included in the table because the interchanged chromosomes had not been determined. They are 7·19 and 8·20 instead of 7·8 and 19·20 of PT 1. This PT was obtained from a single race in Ohio and hence is included among the sporadic PT's.

In the same table, three of the modified chromosomes of *D. pruinosa* and of type 2 of *D. leichhardtii* were left blank. They have since been determined to be 11·16, 12·22, and 15·21. This determination proved especially refractory because of the slight difference in size between the 15·21 and 12·22 chromosomes, and because terminalization is complete at the ·21 end. Inconclusive evidence was furnished by crosses of a PT 3 from *D. quercifolia* and of *D. stramonium* PT 91 with this interchange from *D. pruinosa*, which could be carried along only in the heterozygous condition. This necessitated crosses with *D. ferox* and *D. discolor*. It has not been possible to carry along this same interchange when extracted from type 2 of *leichhardtii*, but previous crosses between it and both *pruinosa* chromosomes and this particular interchange from *pruinosa* have shown that, so far as the chro-

mosome ends are concerned, the interchange is identical in the two species. This conclusion is especially interesting since *D. pruinosa* is endemic in Mexico and *D. leichhardtii* in Australia. Since these two species are rather closely related in morphological characteristics, the geographical location of their common ancestor would be a matter of interest.

As indicated in Year Book No. 40, *D. inoxia* will not cross directly with *D. stramonium* but will cross with *D. leichhardtii*; also it has been impossible to isolate the *stramonium* tester races in the homozygous condition, after repeated backcrosses onto *D. leichhardtii*, with the exception of PT 9. Therefore, in making crosses to *D. inoxia*, it was decided to use these tester races when they are heterozygous, since half the offspring should carry the tester chromosomes. During the past winter heterozygous PT's 2, 3, 7, 10, 17, 34, 40, 49, 61, 90, and 91 were obtained in plants which resemble *D. leichhardtii*. These plants were kept alive during the spring and summer by grafting. They have been used as the female parents in crosses with three tester races of *D. inoxia*, SI's 115, 352, and 1080, and also in crosses with two tester races of *D. meteloides*, SI's 121 and 948. It is hoped that at some time in the near future these seeds can be planted and the chromosomal configurations in the hybrids studied, so that the chromosomal end arrangements of the races of *D. inoxia* and *D. meteloides* can be determined.

The seeds of many of these species crosses rarely germinate, and further difficulty is encountered in the tendency toward asynapsis shown by *D. inoxia* (and to a lesser extent by *D. meteloides*). During the past year a few more hybrids were available for study, so that our knowledge is enlarged somewhat. In figure 1 of the last annual report (Year Book No. 40, p.

224), the chromosome arrangement in the cross between *inoxia* type 2 and homozygous PT 9 is incomplete. This has since been determined to be  $\odot 8 + \text{ch} 8 + \text{ch} 4 + 2$  bivalents ( $\odot$  = circle;  $\text{ch}$  = chain). From the crosses of *inoxia* type 1 and type 2 to *stramonium* PT 9 (20 · 19 · 23 and · 24 chromosomes), 2 of their 12 chromosomes are now known to be the 19 · 20 and 23 · 24 chromosomes. Therefore the end arrangements of these two are identical with two of *stramonium* PT 1.

Also, a plant was obtained from the cross of extracted *stramonium* PT 1 to *inoxia* type 3. It showed  $\odot 10 + \odot 4 + 5 \text{ bv}$ . This  $\odot 10$  indicated that the interchange between *inoxia* type 1 and type 3 involves 1 chromosome from those 4 which induce a  $\odot 8$  and 1 from 2 which induce a  $\odot 4$  with *stramonium* PT 1.

Two species crosses which involve *meteloides* type 1 were studied. The cross of *meteloides* type 1 to *stramonium* 11 · 16 + 12 · 15 gave a hybrid which showed  $\odot 8 + \odot 4 + \odot 4 + \odot 4 + 2 \text{ bv}$ . A cross to *stramonium* PT 9 gave a hybrid which showed  $\text{ch} 10 + \odot 4 + \odot 4 + \odot 4 + \text{bv}$ . The latter cross shows that the 23 · 24 chromosome is involved in the  $\odot 8$  interchange, but the 19 · 20 chromosome has ends identical with those of *stramonium* PT 1.

A cross of *meteloides* type 2 to *stramonium* PT 9 showed a  $\text{ch} 14 + \odot 4 + \odot 4 + \text{bv}$ . This type 2 also has a 19 · 20 chromosome, whereas the 23 · 24 chromosome is involved in the postulated interchange of 6 chromosomes (the cross of type 2 to other species has not yet been studied cytologically). The  $\text{ch} 14$  further indicates that the interchange between *meteloides* type 1 and type 2 involves 1 chromosome from those 4 which induce a  $\odot 8$  and 1 from 2 which induce a  $\odot 4$  with *leichhardtii* type 1.

Although species crosses involving *D. metel* are limited to two rare crosses with

*D. meteloides* and one with *D. inoxia*, 61 races of *D. metel* have been used in *intra se* crosses. This species, which is widely distributed in tropical and semitropical regions, has horticultural value because of the greater variety of flower color and doubleness of corolla. There is only one widespread chromosomal type, but four others have been distinguished. Correlation of these chromosomal types with flower color has disclosed geographical localization of the sporadic types. Completion of this study has been delayed by the slow maturation of *D. metel* in this latitude, many races requiring more than a full year before flowering.

#### PERICLINAL CHIMERAS

Miss Satina has made progress in her analysis of the developmental history of the various organs of *Datura* and the contributions of the three germ layers by means of periclinal chimeras.

In 1941 detailed studies were begun in an attempt to analyze the structure of the carpel in *Datura stramonium* and to determine, by the use of periclinal chimeras, the contribution of each germ layer to the development of the carpel. During the past year this work has been continued and is still in progress. At present it can be stated that the initiation and development of the various parts of the carpel (carpel wall, septum, false septum, and placenta) differ from those of the leaf, sepal, and petal.

The initiation and development of the ovule during very early stages resemble those of the stamen and depend primarily on the activity of the innermost germ layer, L III. The cells of the middle germ layer, L II, form only the subepidermal layer. In later stages, the second layer becomes more active and contributes to the forma-

tion of the nucellus from which the megaspore mother cell differentiates. The integument of the ovule is formed by the cells derived from the outermost germ layer, L I. The megaspore, and later the embryo sac, is covered by the tissue of the integument of epidermal origin, except at the chalazal end, which is formed by cells of the nucellus.

Studies on incompatible  $2n \times 4n$  and  $4n \times 2n$  crosses in *Datura*, which were begun in 1941 with the cooperation of Mrs. E. Sansome, were extended this year. For a better understanding of the processes observed and of the results obtained in the previous year, the crosses were made using as males  $4n$  or  $2n$  plants with the dominant gene Bz. Tetraploid L1 and various types of periclinal chimeras with  $2n$  egg cells ( $4n \ 4n \ 2n$ ;  $2n \ 4n \ 2n$ ;  $2n \ 4n \ 4n$ ;  $8n \ 4n \ 4n$ ) and with  $1n$  egg cells ( $4n \ 2n \ 2n$ ) were used as females. The  $4n \times 2n$  crosses gave a larger number of seeds than the reciprocal crosses, but the germination of these seeds was poorer than in the  $2n \times 4n$  crosses. Two hundred and twenty offspring from 123 pedigrees were brought to maturity; 91 plants were offspring from the  $4n \text{ } \text{♀} \times 2n \text{ } \text{♂}$  crosses, 129 plants from the  $2n \text{ } \text{♀} \times 4n \text{ } \text{♂}$ . The offspring from the  $4n \times 2n$  crosses were predominantly diploid (51  $2n$ , 23  $3n$ , 13  $4n$ , and 4 ?). The offspring from the  $2n \times 4n$  crosses were predominantly tetraploid (113  $4n$ , 2  $3n$ , 3  $2n$ , and 11 ?). All but 4 of these offspring, whether  $2n$ ,  $3n$ , or  $4n$ , carried the Bz gene, and thus they presumably developed from fertilized eggs. Further studies are being made, and seeds have been collected for a survey of the next generation to determine how much of the chromosomal constitution in each case was contributed by the male gamete which was tagged by a dominant gene.

## MUTATIONS FROM BURIED SEEDS

Among the various gene studies under way, perhaps the most interesting is that on the mutation rate from old seed, carried on by Mr. Avery.

In 1933 it was shown by pollen-abortion records that the mutation rate in *Datura* was increased by the aging of seed stored under ordinary laboratory conditions. At that time it was shown that the percentage of mutations found was roughly proportional to the age of the seeds from which the plants came. Seeds less than 1 year old gave a mutation rate of less than 1 per cent. The highest rate, 8.7 per cent, was obtained from seed that was from 7 to 8 years old. Seeds stored under laboratory conditions have failed to germinate when more than 10 years old. There seemed to be an increase of about 1 per cent for each year that the seed had been aged; thus, the rate of mutation obtained from seed 6 years old was 6.1 per cent. In the  $F_2$  generation from these plants a total of 11 new visible types due to mutation was obtained. Mutations of types that show as visible morphological effects were about one-third as frequent as those that caused pollen abortion. The seed used in these experiments was of our highly inbred Line 1. It has been repeatedly shown that the normal rate of mutation in this standard line of *Datura* is very low.

In the summer of 1933 it was possible to obtain samples of soil from the unexcavated parts of the cellar of a house built in Virginia 22 years previously. From these soil samples more than 500 *Datura* plants were obtained. Examinations of the pollen of these plants grown from seed that had apparently been buried for 22 years in the soil revealed that the rate of mutation (1.8 per cent) was scarcely higher than that of the controls, and very much lower than that obtained from seed stored

on the laboratory shelf for less than half as long.

During the past year it has been possible to make a further study of the mutation rate from old seed. Through the kindness of Dr. E. H. Toole, of the U. S. Department of Agriculture, a quantity of *Datura* seed was obtained that had been buried in the open ground for a known length of time. In 1902, samples of a large variety of crop, flower, and weed seeds were buried in the soil near Washington, D. C. The seeds of *Datura* that went into this experiment had been collected from wild plants growing near the Potomac River near Washington. Each sample of seed was placed with soil in a small earthen flower pot and buried directly in the soil. At intervals of 5 or 10 years a few of each lot of seed had been removed and tested for germination by the Department of Agriculture.

From Dr. Toole two lots of seed were obtained: one lot (A) of 188 seeds had been buried at a depth of 18 to 22 inches, the other (B) of 179 seeds had been buried from 36 to 42 inches below the surface. These seeds, with the surrounding soil, were sent to us in sealed metal containers. Upon arrival here the water content of A was found to be 7.15 per cent and that of B, 10.05. Although the seed was more than 39 years old, its germination was exceedingly good. Lot A gave 182 seedlings, or 96.8 per cent, and B gave 176 seedlings, or 98.3 per cent. These plants were grown in the greenhouse during the past winter. The only recordable abnormality among the 356 plants that grew beyond the seedling stage was the frequent occurrence of large or small spots or flecks on the surface of the leaves. These spots were very clearly defined and were usually paler than the surrounding areas. Their exact nature has not yet been determined.

The condition of the pollen of all of these plants was determined. Owing to the unreliability of pollen determinations made of plants grown in the greenhouse, it was impossible to establish a rate of mutation from the occurrence of plants showing high amounts of pollen abortion. Plants that genetically should have a low proportion of aborted pollen may show a high proportion of abortion when grown under greenhouse conditions, although plants with a genetically high proportion of abortion never have consistently normal pollen. As there were very few plants that showed any abnormal pollen abortion, it was evident that there had been very little mutation causing pollen-abortion types.

During the present summer  $F_2$  progenies have been grown from 78 of these plants from 39-year-old seed. Two of these showed segregation for pale-leaved types, and one segregated for a recumbent type called "lazy." In addition to these three new types, which were presumably brought about by recessive mutations, there was one progeny that segregated for a type somewhat resembling the  $2n + 15 \cdot 16$  primary. This also must be recorded as a gene type, since Dr. Bergner has determined it to have the  $2n$  number of chromosomes.

The pollen of these  $F_2$  plants was examined as a further check against the possibility that pollen-abortion types may have been overlooked when the pollen determinations of the parents were made. None of the 78 cultures was found to segregate for individuals with a high percentage of aborted pollen. In view of the fact that four new "visible" types were ob-

tained, it is surprising that no pollen-abortion types were found, as in all previous experiments the pollen-abortion types have been more frequent than the visible types.

From the 78 plants tested by  $F_2$  progenies, there were recovered only these four mutations; this would be a rate of 5.1 per cent. This is considerably higher than that obtained from controls, but is much lower than that obtained from seed "aged" under laboratory conditions.

The low mutation rates obtained from the 39-year-old seed, as well as from those 22 years old, indicate that age alone has little if any part in causing an increase in the rate of mutation in *Datura*. The high mutation rate apparent in plants grown from seed stored on the laboratory shelves was therefore probably brought about by other factors than age alone, probably by the higher temperatures. Experiments conducted jointly with the Boyce Thompson Institute showed that *Datura* seeds held at various high temperatures ( $45^\circ$  to  $80^\circ$  C.) for short periods (2 hours to 5 days) had a higher rate of mutation at the higher temperatures. Although no experimental data are available, it may be suggested that the probable reduction in the amount of oxygen surrounding the buried seed may also have played a part in keeping down the rate of mutation. Plants from either of the lots of buried seeds are not strictly comparable with those of our standard Line 1, which have been used as controls and which also came originally from Washington. There is no evidence, however, that either of the "buried seed" races would be expected to differ from Line 1 in mutability.

## MAIZE GENETICS

BARBARA McCLINTOCK

THE BEHAVIOR OF "UNSATURATED" BROKEN  
ENDS OF CHROMOSOMES

In all cases involving rearrangements of segments of chromosomes which give rise to translocations, inversions, deficiencies, etc., it has been necessary to postulate some force that breaks a chromosome and some force that results in the permanent 2-by-2 fusion of the broken ends. Previous investigations in maize on the mitotic behavior of ring-shaped chromosomes had suggested that fusions may occur between two recently broken ends of chromosomes which enter the same nucleus. Such broken ends may be considered "unsaturated," i.e., capable of fusion with similar "unsaturated" broken ends, until fusion with another broken end occurs or until the end loses its capacity for fusion. To determine whether such an "unsaturated" state exists, male gametes containing a chromosome 9 whose short arm had been broken by mechanical pull at the previous anaphase were united with female gametes containing a similar recently broken chromosome 9. The zygote formed received from each gamete nucleus a single chromosome with a single recently broken end. On the basis of published data, these two recently broken ends, derived from separate nuclei, are believed to be in the "unsaturated" state and therefore capable of fusion with each other. If some force exists that brings these unsaturated ends together and results in fusion, a dicentric chromosome should be produced composed of the chromosome 9 contributed by the female gamete and the chromosome 9 contributed by the male gamete, fused at the ends of their short arms. Through the use of the endosperm markers *I* and *C* and through the aberrant mitotic behavior

that reflects the presence of such broken chromosomes in the endosperm, it was possible to select the kernels from an ear whose zygote nucleus had received a chromosome with an unsaturated broken end from the male and female gamete nuclei, respectively.

Out of a total of 18,243 kernels examined, 20 non-germless kernels were obviously of the type desired. These kernels were germinated. If fusion had occurred between the broken ends of the chromosomes 9 contributed by the two gametes, following chromosome reduplication, the dicentric chromosome should produce a double anaphase bridge configuration when the two centromeres of each chromatid passed to opposite poles. Breakage of the two bridges would result in the entrance into each nucleus of two newly derived, unsaturated broken ends. Fusion of unsaturated broken ends could occur in each sister telophase nucleus. Again, the two chromosomes 9 would be joined to form one chromosome with two centromeres. Repeated anaphase bridge configurations should be expected to follow from such a chromosomal type of breakage-fusion-bridge cycle. Plants having such a dicentric chromosome and undergoing this cycle should have cells with various types of heterozygous and homozygous duplications and deficiencies of the short arm of chromosome 9 following nonmedian breakages of the anaphase bridges. Because of this process, the plants should be conspicuously modified in appearance. The plants arising from 10 of the 20 kernels were obviously of the type expected if a dicentric chromosome 9 were present. Examination of the early roots confirmed the presence of a dicentric chromosome. Some-



what less than one-half of the anaphase figures showed contiguous double bridges. Owing to death or defective growth of many cells or sectors of tissue, 5 of these plants died in the seedling stage. Four of the remaining 5 plants continued to grow, because sectors of normal-appearing tissues developed. Gradually these sectors gained the ascendancy in growth, until the plant appeared quite normal. The fifth plant produced 3 normal shoots, which arose from the base of the decidedly aberrant and dying main shoot. Microsporocytes were obtained from the 4 recovered plants and from 2 of the 3 recovered shoots of the fifth plant. In all cases, pachytene analysis showed a bivalent chromosome 9. The two chromosomes were not fused at the ends of their short arms. The two broken ends had healed in the ancestor cell which gave rise to the recovered sector. In most cases, the composition of the short arm of each member of the bivalent was greatly modified, although within a tassel sample all examined sporocytes showed the same composition for the individual member of the bivalent. In several of these plants, it was possible to determine the minimum number of fusions, breakages, and bridges which must have occurred before healing of the two broken ends within a single nucleus had occurred. It is likewise known that the compositions of the short arms were entirely different in the sporocytes of the tassels of the 3 recovered shoots of the one original dicentric plant. The two chromosomes 9, however, had maintained their respective derived compositions within each shoot. This indicates that the microsporocyte tissues of each shoot had originated from one individual cell whose cell ancestors had previously been undergoing the chromosomal type of breakage-fusion-bridge cycle involving the original dicentric chromosome 9. The root system

responded similarly. In the older roots of the surviving plants, no dicentric anaphase bridge configurations were observed.

These experiments definitely show the existence of an "unsaturated" state of a recently broken end of a chromosome. Owing to causes as yet undetermined, however, such an end may become saturated (healed) without fusion. Following this, the end no longer takes part in any fusions.

The remaining 10 of the original 20 kernels classified as having received a broken chromosome 9 from each parent gave rise to 9 normal-appearing plants and 1 pale-yellow plant which died in the seedling stage. None of these plants showed dicentric bridge configurations in the young roots. Examination of the sporocytes of the 9 surviving plants showed that 4 had received a broken chromosome 9 from each parent; but the morphology of the short arms gave no indication that fusions had occurred between these broken ends. In 1 plant one parent had contributed a broken chromosome 9, but it could not be determined whether the other parent had likewise contributed a broken chromosome 9. In the remaining 4 plants, each parent had contributed a broken chromosome 9, but one broken end had become saturated by fusion with a broken end other than that of the chromosome 9 contributed by the second gamete and possibly before fusion of the gametes themselves. Consequently, healing of the broken end of the second chromosome 9 had occurred. These results indicate that an unsaturated broken end produced by mechanical breakage of an anaphase bridge is capable of fusing with another unsaturated broken end arising from undetermined causes.

A similar type of fusion has likewise been observed in sporocytes of 5 plants which were known to have been derived

from a gametophyte which had received a chromosome 9 with an unsaturated broken end. It is known that mechanical pull caused by an anaphase bridge will frequently break a chromosome at a knob or at the centromere. In 2 of the 5 cases, the centromere of the broken chromosome 9 was fused with the centromere of another chromosome of the complement. In one case, the fused chromosome was composed of the long arm of chromosome 9 and the short arm of chromosome 2. In the second case, it was composed of the long arm of chromosome 9 and the short arm of chromosome 10. In each case, the complementary arm was missing. In three cases, the fusions had occurred at other positions than centromeres. In one case, a segment from the long arm of chromosome 4 had united with the broken end of the short arm of chromosome 9. Since both chromosomes 4 in this plant were completely normal, it is assumed that chromatid fusion in a gametophytic nucleus had occurred between the unsaturated broken end of chromosome 9 and a naturally arising broken end terminating an acentric distal segment of chromosome 4. In the other two cases, both segments of the second broken chromosome were present. Pachytene analysis has led to the following interpretation: In the last two cases mentioned, a break occurred at one position in chromosomes 1 and 8, respectively. In both cases, this resulted in the presence of three unsaturated broken ends in the same nucleus, one of which was the broken end of the short arm of chromosome 9. Fusion occurred between the unsaturated broken end of chromosome 9 and the unsaturated broken end of the acentric segment of the second broken chromosome. This left the centric segment of the second broken chromosome with a single unsaturated broken end, which thereafter healed. This healing of a single un-

saturated broken end, when introduced into sporophytic tissues, is in agreement with the results of similar investigations of this behavior.

#### PHENOTYPIC EFFECTS OF HOMOZYGOUS DEFICIENCIES OF DISTAL SEGMENTS OF THE SHORT ARM OF CHROMOSOME 9

The phenotypic effects in male gametophytes, and in endosperm and sporophytic tissues, of a series of homozygous deficiencies involving distal segments of the short arm of chromosome 9 are being investigated. These deficiencies were obtained through meiotic breakage of a dicentric chromatid 9 which had been produced following crossing over involving a duplicated segment of the short arm of chromosome 9. This method has been previously described (McClintock, 1941; see bibliography). A number of terminal deficiencies have been isolated, ranging in length from a fraction of the terminal chromomere to deficiencies of approximately one-third of the short arm, including the locus of *C*. At pachytene, the short arm of chromosome 9 has approximately 20 chromomeres. Those in the proximal third of the arm are large, those in the distal two-thirds of the arm are small.

*The effect of homozygous deficiencies on the functioning of female gametophytes.* Plants heterozygous for these deficiencies produce female gametophytes which are totally deficient for the respective segments of chromosome 9. Complete functioning of such gametophytes occurs in all cases of short deficiencies. Only in the case of longer deficiencies which include 4 or more chromomeres is there a reduction in the functioning of such gametophytes. Environmental factors may be involved in this differential functioning. A preliminary test has indicated that, on a single ear, functioning of deficient female

gametophytes may be complete on one day and they may be totally nonfunctional on the succeeding day. Extensive tests are necessary to associate the effect with a particular environmental condition.

*The effect of homozygous deficiencies on the appearance and functioning of male gametophytes.* Plants heterozygous for these terminal deficiencies produce pollen grains one-half of which carry the deficient chromosome 9. In all cases, homozygous deficient pollen grains are completely filled with starch. Only in the case of deficiencies that include the distal one-third of the short arm is it possible to distinguish any perceptible differences in the appearance of the normal and the homozygous deficient grains. The latter grains appear to be smaller, but an exact identification of each grain has not been possible. Only in the case of distal deficiencies that are greater than one-third of the short arm is there a classifiable visible effect on pollen development. Some starch develops even in pollen grains that are deficient for nearly all of the short arm of chromosome 9.

Pollen grains that are deficient for small terminal segments are completely functional. Those deficient for more than the terminal chromomere, although completely normal in appearance, are nonfunctional.

*The phenotypic effects of small terminal deficiencies on endosperm and sporophytic tissues: the deficiency mutants "pale-yellow" and "white" and their dominance relationships.* Plants that are heterozygous for small terminal deficiencies produce viable and functional male and female gametophytes. These plants were selfed to determine whether viable endosperms and embryos that were homozygous for these deficiencies could be obtained. In 5 of the 7 cases studied, the endosperm and embryo of kernels having the homozygous deficiencies were completely normal in ap-

pearance. In 2 cases, some but not all of the embryos that were homozygous deficient had died before the maturity of the kernel. The endosperm of these kernels, however, was completely normal. In all 5 cases with normal embryo development, pale-yellow seedlings, completely normal in gross morphology and growth rate, grew from these kernels. Although the coleoptiles were light green, little chlorophyll developed in the leaves, and the seedlings died after exhaustion of the food reserves in the endosperm. The surviving embryos in the 2 cases where the homozygous deficiency resulted in early death of some embryos produced white seedlings completely devoid of plastid pigments. Although the gross morphology of these seedlings was normal, the growth rate was considerably retarded. Proof of the association of the pale-yellow and white seedlings with the homozygous deficient state was obtained through cytological examination of normal sibs, which had only homozygous normal and heterozygous deficient chromosomes; through crosses of these latter plants to plants heterozygous for longer deficiencies, where the mutant types appeared only from unions of the two respective deficient chromosomes; through close if not complete linkage with the mutant *yg* located near the end of the short arm of chromosome 9; and through chromosomal examination within white sectors of sectorial plants.

Intercrosses among all 7 cases have shown that the 5 pale-yellow mutants are allelic and that the 2 white-seedling mutants are allelic to pale-yellow, with pale-yellow dominant to white. The 5 deficiencies giving rise to pale-yellow do not include the *yg* locus, whereas the 2 deficiencies giving rise to white seedlings may include this locus. The deficiencies giving rise to white seedlings are longer than those giving rise to pale-yellow seedlings,

although they have a deficient segment in common. This accounts for the allelic nature of the two mutants and the dominance of pale-yellow over white. The pale-yellow and white mutants represent typical Mendelizing mutants, which are associated with a state of homozygous deficiency. Dominance in these cases is an expression of the extent of the deficiency: no deficiency produces green seedlings, a short terminal deficiency produces pale-yellow seedlings, and a longer terminal deficiency produces white seedlings, with dominance expressed in this order.

*The phenotypic effects of relatively long terminal homozygous deficiencies.* Terminal deficiencies that include more than one chromomere do not give rise to functional pollen. Thus, the phenotypic effects of these deficiencies could not be studied by the direct method of selfing heterozygous plants. Instead, the variegation method, which produces sectors of tissue that are homozygous deficient, was introduced in these cases. This method utilizes the aberrant mitotic behavior of recently broken chromosomes, which, in the endosperm, continuously deletes segments from the arm of the chromosome which has the broken end. If the female gametophyte contributed 2 deficient chromosomes, and the male gametophyte contributed a chromosome 9 whose short arm terminated in a recently broken end, the developing endosperm could be sectorial for homozygous deficient tissues. The endosperm mutants *C* (aleurone color), *I* (inhibitor of aleurone color, allelic and dominant to *C*), *Sh* (*sh*, shrunken endosperm), and *Wx* (*wx*, waxy starch) were used to mark the chromosomes contributed by the two parents. The preliminary investigations on the effects of homozygous deficiencies on endosperm development may be summarized as follows: Endosperm development may be completely normal when homozy-

gous deficiencies up to and including two terminal chromomeres are present. Beyond this region, only patches of such homozygous deficient tissue, surrounded by normal tissues, will develop. As the homozygous deficiency becomes progressively longer, the rate of development within the sector is reduced. Although the *C* locus may still be present, aleurone-color development progressively diminishes until only the rim of cells bordering normal cells shows color. Apparently, some substance or substances diffuse from the normal cells into these homozygous deficient cells, allowing them to develop normal aleurone color. This material, however, either does not diffuse beyond a layer several cells deep or is used up before deeper penetration occurs. Starch development occurs in all the patches of homozygous deficient cells except when the deficiency approaches the distal third of the short arm and includes the locus of *C*. In the latter case, relatively extensive growth of the homozygous deficient cells occurs; but, owing to lack of starch formation in these cells, a shrinkage leading to scar formation occurs after drying of the kernels.

To study the effects of various homozygous deficiencies on sporophytic tissues, the method of covering a deficiency with a ring-shaped chromosome may be utilized. Frequent losses of the ring-shaped chromosome during mitoses should produce cells that are homozygous deficient. Cells arising from these cells should produce sectors capable of expressing changes that could be related to the homozygous deficient state. Likewise, changes in constitution of ring chromosomes, which may delete segments from the ring, could produce sectors that are homozygous deficient for various segments within the limits of the full deficiency. Only two such plants

have been produced. Both plants were characterized by numerous sectors of white, pale-yellow, and yellow-green tissues. Although these sectors probably represent the expression of homozygous deficiencies, no conclusions will be drawn until this method receives more detailed and controlled analysis.

A deficiency of one-third of the short arm of chromosome 9 is relatively long,

but none of these deficiencies have been cell lethal in any of the tissues studied. It is altogether possible that the observed effects of the homozygous deficiencies in the various tissues may be related to a few specific loci within the limits of the distal third of the short arm, rather than to the accumulative effect of a large number of such loci. This would be understandable if maize were a derived polyploid.

## POLYPLOIDY INVESTIGATIONS

H. E. WARMKE

### THE MARIHUANA CONTENT OF HEMP

In addition to producing valuable fiber, hemp (*Cannabis sativa*) also produces the undesirable drug marihuana. With the huge plantings of this species throughout the nation necessitated by the interruption of fiber shipments from abroad, the problem of control of this drug threatens to become a difficult one. For this reason, Drs. Barre and Robinson, of the Division of Cotton and Other Fiber Crops, Bureau of Plant Industry, U. S. Department of Agriculture, suggested that the Department of Genetics help on a project started by them some time ago: that of producing a strain of hemp with materially reduced marihuana content, if such is possible, by methods of selection and breeding.

Several superior fiber strains were supplied, and have been tested for drug content during the past season, using a modification of the bio-assay method of Robinson (1941). This method, as modified by the present workers, is based on the toxicity to the fish *Fundulus heteroclitus* of different dilutions of acetone extracts of weighed samples of dry leaves, and has proved to be a completely practical method of marihuana assay. A series of four decreasing dilutions, each containing 2 fish, is used to test each plant; and records are

kept of the number of fish killed, the limits being 0 fish killed for plants with low drug content and 8 fish killed for plants with extremely high drug content. Such an assay, of course, does not give absolute concentrations, but it does provide an estimate of the relative amounts of drug present in the series of plants being tested.

Over 1000 marihuana determinations have been run during the course of the summer; results of tests on some 258 plants are given graphically in figure 1. It is of interest that the plants tested, although growing under as nearly identical conditions as possible, vary widely in marihuana content. For example, 10 plants were found whose extracts failed to kill a single fish, even in the strongest concentration, and 1 plant was found which killed fish through all concentrations, including the most dilute.

On the basis of dilutions used, this would represent an eightfold range in marihuana content, and is extremely encouraging as a starting point for selection and breeding experiments. If these differences are largely genetically controlled, by intercrossing the plants on the left of figure 1 we should expect to obtain races in subsequent generations with greatly reduced average marihuana content. Of course, marihuana

content is thought to be influenced by both genetic and environmental factors, and only further tests can show which of these factors is predominant in producing the array of potencies represented in figure 1.

The data in figure 1 were regrouped so as to give a comparison of marihuana content of male and female plants. The 116 females represented in this array killed an average of 3.5 fish per test, and the 86

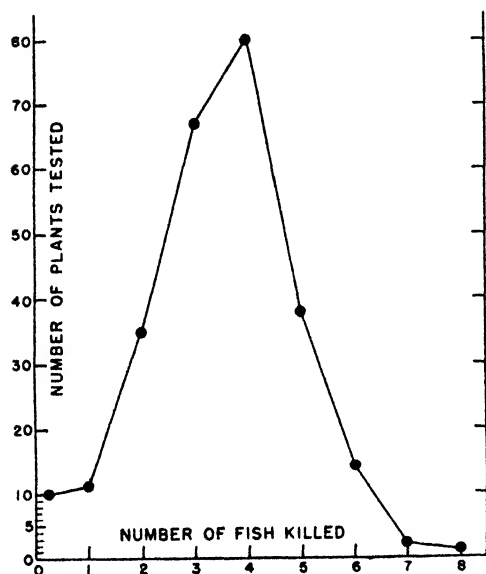


FIG. 1. Relative marihuana concentrations in 258 hemp plants as indicated by toxicity to fish of acetone extracts of dry leaves. Zero fish killed indicates plant with low toxicity; 8 fish killed indicates plant with high toxicity.

males killed an average of 3.7 fish. These differences probably are not significant, and confirm the conclusions from previous limited chemical tests (Matchett and others, 1940) that no important sex difference in marihuana content exists.

Tests of single entire hemp leaves have shown an unmistakable gradient in alkaloid content extending from bottom to top of the plant. The bottom leaves have an extremely low alkaloid concentration, the top leaves a very high one. This find-

ing called attention to the necessity of exercising caution in taking leaf samples for marihuana determinations, and eventually led to the adoption of a method using the center leaflet from each leaf on the plant, rather than selected whole leaves as had been done previously.

#### POLYPLOIDY AND MARIHUANA CONTENT

Marihuana determinations were also run on our original autopolyploid races of hemp in order to determine whether alkaloid content is affected by increase in chromosome number. These polyploid races, although not inbred, were all derived from the same original diploid strain, and therefore have a comparable genetic background.

The results of these tests, based on determinations from 25 plants for each member of the series, are as follows:

Polyploid	Average no. fish killed
Diploid .....	1.4
Triploid .....	3.0
Tetraploid .....	2.6

This indicates a definite increase in marihuana content in the triploid and tetraploid races, which of course could not have been predicted in advance.

A similar increase in vitamin C content in autotetraploid tomatoes has been reported by Sansome and Zilva (1933); and Randolph and Hand have recently found an increased concentration of vitamin A in autotetraploid corn. Cases of this nature, where the autopolyploid produces a chemical product in a different concentration from its related diploid, are beginning to be noted; these throw important light on the mechanism of gene balance and action.

The slightly greater drug content in triploids than in tetraploids in these tests

is out of line in the polyploid series. Whether this difference will be borne out with more extensive testing is not known; it was found consistently, however, among the plants in this series of tests.

Before these marihuana determinations on polyploids were made, samples of seed of our established diploid and tetraploid races had been submitted to the Department of Agriculture for comparative tests of fiber quality and quantity. The robust habit of the tetraploid had suggested a possible superiority in fiber content. It would now appear that the tetraploid race will be less desirable than the diploid from the standpoint of drug content; final judgment on its over-all value, however, must await the results of the fiber tests now in progress.

#### THE RUSSIAN DANDELION

In May 1942, Dr. E. W. Brandes, in charge of special rubber investigations of the Bureau of Plant Industry, requested the Department to undertake a cytogenetic study of the rubber-bearing Russian dandelion (*Taraxacum kok-saghyz*). The purpose of the investigation was to ascertain the chromosome number and reproductive behavior, in order to lay a foundation for the intelligent growing and breeding of this species in America. Some 2000 plants have been grown in the greenhouses and out of doors during the past season. A sufficient number of these have come into flower so that certain findings can be reported at this time. These findings generally are in agreement with those of the Russian workers Poddubnaja-Arnoldi and Dianowa.

*Taraxacum kok-saghyz* is a basic diploid in the genus, with a chromosome number of  $n = 8$ ;  $2n = 16$ , at least one pair of which bear satellites. Those plants that have reached the flowering stage to date fail to

set seed when isolated in the greenhouses, but set seed abundantly out of doors or when manually cross-pollinated in the greenhouse. This indicates the species to be self-sterile, but fully cross-fertile.

Studies now in progress indicate that gamete formation is normal on both the male and female sides. The formation of the female gamete, which is often abnormal in the common species of dandelion, leading to the parthenogenetic development of an unreduced egg cell, appears to follow the normal sexual pattern in *T. kok-saghyz*. The archesporial cell enlarges and undergoes a normal meiosis to form a linear series of 4 reduced megaspores, the chalazal one of which develops into a normal 8-celled embryo sac.

These conditions are extremely fortunate from a practical point of view, because they make selecting and breeding experiments possible. Since *T. kok-saghyz* is a member of the Compositae, experimental breeding would have been extremely difficult had it proved self-fertile or parthenogenetic.

Several hundred colchicine-treated plants are also being grown in an effort to obtain a tetraploid race. On the chance that the tetraploid might show altered, and possibly desirable, rubber-producing qualities, it seemed of value to treat a group of plants. Many of these have been markedly affected by the treatment, as indicated by rough and thick leaves. Pollen-size determinations of four treated plants that are now in flower show one to be tetraploid; so it is hoped that a tetraploid race may be established sometime this winter.

#### THE SEX MECHANISM IN *SILENE OTITES*

*Silene otites* is a dioecious plant, but whether the male or female is heterogametic (XY) cannot be determined by cy-

tological methods, because of similarity in size of the sex chromosomes. Sansome (1938) has reported the female to be heterogametic on the basis of indirect evidence obtained from interspecific hybrids. By doubling the chromosome number in this species and utilizing the peculiar breeding behavior of the  $4n$  sex heterozygote, it has been possible to present extremely good evidence to the contrary: that the male is XY.

The method is as follows: Using colchicine, XX and XY plants are transformed into XXXX and XXYY plants, respectively. The XXXX individuals will produce only XX gametes, but the XXYY individuals will produce at least 1 XX:4 XY:1 YY gametes. A higher proportion of XY gametes will result if differentiation of the sex chromosomes is sufficient to disturb random pairing. When XXXX and XXYY individuals are crossed, therefore, three types of offspring are expected: 1 XXXX:4 XXXY:1 XXYY. In *Silene*, approximately 5 males to 1 female are obtained when treated  $4n$  males and females are crossed, which indicates two classes of males: 1 XXYY and 4 XXXY, or 1 XXXX and 4 XXXY, depending upon whether the female is XXXX or XXYY. To determine the constitution of the female, several of the treated  $4n$  females are crossed to diploid males (and reciprocal if possible). If the female is XXXX, a  $3n$  population of 1 male to 1 female should result; if it is XXYY, 5 males to 1 female would be expected. In *Silene* this cross has produced triploid males and females in a ratio that does not deviate significantly from 1:1. This indicates that females are

homogametic and males are heterogametic, and makes possible the interpretation of breeding results on the same basis as in *Melandrium*.

Further evidence is being sought by intercrossing tetraploid males and females from 1:1 pedigrees. If the above explanation is correct, these should give only 1:1 populations; if it is incorrect, ratios other than 1:1 should be observed. It seems likely that these methods may find wide application in determining the heterogametic sex in species other than *S. otites*.

#### A GYNODIOECIOUS RACE IN MELANDRIUM

One of the results of the inbreeding program being carried on with *Melandrium* (Year Books Nos. 39 and 40) is the establishment of a diploid race consisting of XX females and XY male-hermaphrodites. This race arose by the recovery of XX and XY types from the self of selected strongly female XXY types.

When these XX and XY types are crossed, females and male-hermaphrodites appear in approximately a 1:1 ratio. The XY male-hermaphrodites, when selfed, produce females and male-hermaphrodites in the ratio of approximately 1:3 (10:33). The securing of selfed offspring from the XY plants was of extreme interest because it afforded an opportunity to obtain YY individuals, a type reported in some other species but never in *Melandrium*. The cytological analysis of 26 of the male types from these pedigrees, however, has shown only plants with X and Y chromosomes, which probably indicates the YY type to be inviable.



## THE GENE

M. DEMEREC, B. P. KAUFMANN, U. FANO, EILEEN SUTTON, AND EVA R. SANSOME

## GENE POSITION AND ACTION

*A gene increasing mutability.* It was noted in various experiments conducted by Dr. Demerec that X-chromosome lethals originated with much higher frequency in certain males from the wild-type Swedish-b stock than in their brothers. Further tests indicated that such males contain a gene that increases the rate of mutability of other genes. Experiments are now under way to isolate this gene and to study its behavior. It appears that this mutability gene is similar to the one found earlier in the wild-type Florida stock and described in Year Book No. 35 (1935-1936), pages 43-45.

*Semisterility genes in Drosophila.* Attempts to investigate and reduce the sterility of untreated *Drosophila* material, in order to improve the conditions for accurate measurement of dominant lethals, were reported in Year Book No. 40 by Dr. Fano. These attempts resulted in the isolation from Swedish-b stock of a new recessive semisterility character, located in the second chromosome and effective only in females. A majority of the eggs laid by females that are semisterile (*sst*) fails to hatch. Counts of the offspring of 27 *sst* females showed that the proportion of eggs hatching varied between 12 per cent and 52 per cent. Genetic characters inducing complete sterility have frequently been reported in the literature, but the new character described here seems to belong to a less well recognized type. It might have been expected that the constitutional characteristics of a female affecting the degree of viability of its offspring would be determined by the collective action of a large number of factors, each of them only slightly important in itself. The identifica-

tion of the factor *sst* indicates that this is not so. This one character brings about very striking effects; but the experiments indicate that weaker characters having analogous effects are so widespread among laboratory stocks as to make it difficult to isolate high-fertility strains.

*Cytogenetic analysis of the Bar locus.* The analysis of our stocks of Bar, double-Bar, and double infra-Bar confirmed Bridges' (1935) cytological analysis of the first two, and showed no detectable difference between double-Bar and double infra-Bar.

Twenty-nine changes at the Bar locus (changes from wild-type to Bar, from Bar to or toward wild-type, and from double-Bar and double infra-Bar to or toward wild-type) have been analyzed cytologically and genetically by Dr. Sutton.

The Bar locus appears to be associated with the band 16A1·2 of the salivary-gland X chromosome, and the Bar phenotype is produced by a limited number of the possible rearrangements in which this locus is brought into immediate contact with loci in other parts of the chromosomes. The Bar effect is thus a position effect, and is not essentially different from other known position effects. In no case has the Bar effect been produced by mutation of the Bar locus without rearrangement, but reversions of Bar to normal can be brought about by mutation or inactivation of the Bar locus or the adjacent interacting locus. In the original Bar stock the position effect seems to be produced by the contiguity of the bands 16A1·2 and 16A7, and in double-Bar and double infra-Bar this association of bands is duplicated. Complete reversions of double-Bar or double infra-Bar to wild-type have been

obtained by irradiation, without any visible change in the chromosomes, and these phenotypic changes must be due to simultaneous inactivation of both associations of the interacting loci.

*Location of genes in the salivary-gland X chromosome.* Over a period of eight years, all spontaneous and induced changes obtained in loci in the X chromosome have been analyzed both genetically and cytologically. The genetic tests determined all loci affected in each case, and the cytological analysis of salivary-gland chromosomes determined what chromosomal aberrations, if any, were associated with the genetic changes. The accumulated data have made it possible to correlate particular genes with single bands or strictly delimited regions of the salivary-gland X chromosome. The following genes have been located in this way: *y* and *ac* (1A5-8), *sc* (1B3-4), *svr* (1B5,6), *M(1)Bld* (1B11-1C2-3), *sta*, *tw*, and *br* (1C4-5-2C10), *pn* (2D5,6), *kz* (2E1-2-2F6), *w* (3C2-3), *rst* (3C4), *N* (3C7), *dm* (3D1-2), *M(1)3E* (3E3-4), *ec* (3F1-2), *M(1)4BC* (4B5-4C5-6), *bi*, *peb*, and *rb* (4C7-8-4D1-2), *rg* (4E1-3), *cx* and *cv* (4F1-2-5D1-2), *rux* and *vs* (5D3-4-6A1-2), *dx*, *shf*, *scp*, and *cm* (6A3-4-6F10-11), *ct* (7B3,4), *sn*, *oc*, *ptg*, *dd*, *tbd*, and *con* (7C4-5-8C1-2), *t* and *lz* (8C3-17), *dvr* (to right of 8D8-9), *m* (10C3-4-E1-2), *dy* (to right of 10E1-2), *M(1)o* (15B1-2-E7), *f* (15F1-5), *B* (16A1-2).

*Mutants of Drosophila melanogaster.* The compilation of descriptions of the mutants of *Drosophila melanogaster* made by Dr. C. B. Bridges and printed in first draft in 1938 as *Drosophila Information Service* No. 9 has been completed and edited by Dr. Katherine S. Brehme, and is to be entitled "The mutants of *Drosophila melanogaster*." In preparing the first draft, Dr. Bridges utilized the mutation list which he had maintained and continually revised

since 1914, and which included the data concerning all significant mutations and reoccurrences found by him and other members of the laboratory of Dr. T. H. Morgan. He also used the information published in the Carnegie monographs and in *Drosophila Information Service* Nos. 1-8. Special contributions of new data were made by a number of investigators. After the death of Dr. Bridges, a systematic survey of the literature was made by Dr. Brehme, covering all available publications on the genetics of *Drosophila* through August 1942. An attempt was made to include such information concerning the mutations as would be of use to investigators, and to document all data as thoroughly as possible. Each person responsible for the original description of a mutant was consulted concerning the accuracy of the description included in the volume, and was asked to contribute new data. In this part of the work, fifty-eight investigators were generous contributors and consultants. Many of the illustrations used in the volume are the work of Miss Edith M. Wallace; some of her drawings are here published for the first time, and some are republished. Other illustrations are reprinted from the publications of many workers, and have been redrawn by Miss Alice Hellmer or photographed by Miss Ruby Gay Stewartson. The finished manuscript was critically read as a whole by Drs. M. Demerec, T. H. Morgan, J. Schultz, C. Stern, and A. H. Sturtevant, and in part by several other authorities; and their suggestions have, so far as possible, been faithfully carried out.

*Ultraviolet absorption in the salivary-gland chromosomes of mottled phenotypes.* The work on ultraviolet absorption (see *Year Book* No. 40) has been continued by Dr. P. A. Cole and Dr. Sutton at the National Institute of Health, Bethesda, Maryland. One of the aims of this work

was to investigate a possible correlation between phenotypic variegation, due to translocation of genes to heterochromatin, and the variation in absorption of ultraviolet by the bands with which these genes are associated. Larvae of two genotypes were used, one of which ( $w^{mot} 258-21/y\ sc\ w; Cy/+$ ) shows rather slight variegation of the adult eye at  $18^{\circ}\text{C}$ ., associated with an X-4 translocation. The other type ( $w^{mot} 258-21/y\ sc\ w; Ms10/+$ ) has the same translocation together with a second-chromosome modifier which increases the phenotypic variegation so that the eye is largely white, with a few small flecks of red facets. A set of ultraviolet photomicrographs was made from larvae of each type. If there is a close correlation between the nucleic acid content of the bands and the degree of phenotypic variegation, a comparison of absorption by the normal and translocated bands in each set of photographs should show a significant difference between the two sets.

Analysis of the data is now in progress. Inspection of the plates by eye does not reveal any marked difference between the two sets. Measurements of the plates have been made by means of a recording microphotometer in the laboratory of Dr. I. Gersh, Department of Anatomy, Johns Hopkins Medical School, Baltimore, and the calculation of extinction coefficients from these measurements is now in progress.

*Experiments with heavy water (deuterium oxide).* Dr. Stephen Zamenhof and Dr. Demerec conducted a series of experiments in which one generation of *Drosophila* was raised on food containing either 40 per cent or 55 per cent of heavy water. The males thus obtained were tested for X-chromosome lethals by the standard ClB method. It is known that if water containing deuterium reaches an

organic compound, hydrogens that are connected with N and O exchange with the deuterium almost instantly, in a ratio corresponding to the deuterium/hydrogen ratio in the surrounding water. This exchange is easily reversible, and if pure water subsequently reaches this compound all the deuterium is replaced again by hydrogen. Thus, in the present experiment it is estimated that the genes contained up to 30 per cent of C-connected deuterium and up to 40 per cent of N- and O-connected deuterium in place of hydrogen. Tests made on about 2000 treated sperms showed no increase in the frequency of lethals in treated flies as compared with controls. There are at least two possible explanations of these results. One is that the substitution of deuterium for hydrogen did not change either the structure or the activity of the gene; another possibility is that the gene structure did change, but was able to return to its original form as soon as deuterium was replaced by hydrogen.

#### CHROMOSOME BREAKAGE AND RECOMBINATION

Chromosomal rearrangements in *Drosophila* may be induced by X-ray treatment of spermatozoa of the adult male. As was reported in Year Book No. 39, evidence has been collected which indicates that although the potential breaks are induced in the mature sperm, new combinations of chromosomes do not arise until after the sperm nucleus has penetrated the egg. Since the interval between irradiation of the sperms and their utilization in fertilization can be extended over many days without the occurrence of break recombination or restitution, an opportunity is offered to attempt to alter these phenomena experimentally. Ability to alter the customary behavior of the X-ray-

sensitized regions might throw some light on the nature of the disturbances produced in the chromosomes by irradiation.

Presumably the chromosomes, following X radiation, are in a highly "labile" state, and in this condition may be sensitive to types of treatment that leave no imprint on the genetic constitution of the normal cell. Supplementary energy necessary to affect the regions of potential breakage might conceivably be supplied either by chemical or by physical agents. Use of the former seems less desirable because of the difficulty of securing penetration into the nucleus without impairing or destroying the vital functions of the cell. An approach offering more promise of success is the use of radiant energy.

In line with these considerations, a series of experiments have been designed by Drs. Kaufmann and Hollaender to measure the effects of several wave lengths in the near infrared and ultraviolet portions of the spectrum. So far as is known from a series of control experiments, neither of these agents is in itself instrumental in causing gross chromosomal derangements. The near infrared rays can be produced quite readily in high intensities, they are absorbed only slightly by water, and they penetrate well into living tissues. Rays in the range between 8000 and 15,000 Å, obtained from a high-intensity source, have been concentrated on the *Drosophila* males, which were retained in a glass vial surrounded by a cooling coil. Results of these first experiments indicate that with increasing exposure to the infrared there is a decrease in the frequency both of altered sperms and of chromosomal breaks, as measured by cytological analysis of the F<sub>1</sub> salivary glands of larval descendants of irradiated fathers. Thus, in one set of experiments in which 2000 roentgens of X rays were given, followed by infrared

and then another 2000 r, these values were obtained:

Hours infrared	% altered sperms	% breaks
72.....	26.7	66.4
144.....	20.9	58.9
216.....	14.1	32.1

Control values for 4000 r (given in either single or fraction treatments) are about 30 per cent altered sperms and 86 per cent breaks.

Within the ultraviolet portion of the spectrum, the wave length 2537 Å has been tested. Radiation of this type is most fully absorbed by the nucleic acid component of the chromosomes. Males exposed to a combined treatment of 4000 r plus the ultraviolet also gave much lower values than the X-ray controls, namely, 14.5 per cent altered sperms and 36.3 per cent breaks.

Since these are only preliminary experiments, full appraisal of the physical and biological factors involved must await the compilation of additional data, including a more complete set of controls. One possible explanation of the results is that the supplementary radiation serves to accelerate the process of repair or restitution that occurs naturally in some of the potential breaks induced by X radiation.

The frequency with which such natural restitution occurs has been given further consideration by Dr. Fano. In Year Books Nos. 39 and 40, attention was directed to some theoretical and experimental approaches to the correlation of data on chromosomal changes, obtained by observations of dominant lethals and other cytogenetic techniques. It had been found that most of the lethals produced by low dosages of X rays behave as if they were due to single-break processes. Certain difficulties, which at that time seemed to prevent full acceptance of this hypothesis,

have now been removed by the work of G. Pontecorvo, of the University of Edinburgh. We may thus accept the conclusion based on our data that single breaks are produced in *Drosophila* sperms at a rate of about 15 per cent per 1000 r of X rays. It is, however, not immediately clear whether most of the cases with a single breakage result in dominant lethals, or whether many of the single breaks "heal," thus to become completely obliterated. Data collected by other authors on different materials indicate that the second alternative obtains; and the following considerations applying to *Drosophila* point in the same direction.

If no other breakages were available than those detected by dominant-lethal counts, and assuming that individual breakages occur independently of one another, the frequencies of the occurrence of different numbers of breaks in the same sperm should follow a Poisson distribution. Accordingly, the expected frequency of sperms with two breaks at 1000 r ought to be approximately  $\frac{1}{2}(0.15)^2 \approx 1\%$ . This figure is far too low to account for the frequency ( $\approx 3\%$ ) of viable two-break rearrangements, so that we may conclude that the average frequency of potential or actual breakages at 1000 r considerably exceeds 15 per cent.

The number of points of potential breakage induced within a single nucleus may also be much greater than had been anticipated on the basis of the complexity of previously observed rearrangements. In earlier experiments a 14-break case had been analyzed; in the course of the studies combining X rays with the near infrared, a rearrangement was found by Kaufmann which involved at least 32 points of breakage. The positions of 30 of these breaks have been determined; others restricted to the proximal heterochromatin remain of uncertain location. Distribution of identi-

fiable breakage points among the chromosomes is as follows: 6 in the X chromosome, 3 in the left limb of the second chromosome (2L), 5 in 2R, 3 in 3L, 12 in 3R, 1 in the fourth chromosome. Aside from its great complexity, this rearrangement is particularly interesting because of the accumulation of breaks in the right limb of the third chromosome. The probability of such a distribution on a chance basis is very small (between 0.02 and 0.05 on the basis of the  $\chi^2$  test). In the light of this finding, our other data on complex rearrangements are being examined more fully in an effort to secure additional information concerning the nature of the breakage-recombination phenomenon.

Another pair of glands analyzed in these studies illustrates the ability of two sister strands obtained from an irradiated chromosome to recombine independently of each other. These glands consisted of a mosaic of tissue containing two types of nuclei. One showed a mutual exchange between the 2R, 3L, and 3R chromosome limbs to give the following sequence of parts:

2L tip.....centromere.....60D/79B .....tip 3L  
3R tip...98D/79B....centromere...98D/60D...tip 2R

The remaining nuclei revealed a reciprocal translocation of the following type:

2L tip.....centromere.....60D/79B .....tip 3L  
2R tip..60D/79B.....centromere.....tip 3R

Although the two patterns of recombination differ with respect to the participation of the right limb of the third chromosome, the sequence of events responsible for this condition must remain, as in other similar cases, open to various interpretations. If it is assumed that the chromosomes of the irradiated sperm are unsplit and that all regions of potential breakage are duplicated in the derived sister chromatids, we must further postulate that

restitution has occurred in one of the 3R strands. On the other hand, we cannot eliminate the possibility that the chromosomes of the sperm are already split longitudinally and that sister strands may respond either identically or independently within the same nucleus.

#### NEUTRON EXPERIMENTS

Two peculiar facts have been reported in the literature concerning the distribution of neutron-induced recessive sex-linked lethals in *Drosophila*. Nagai and Locher have reported a nonrandom distribution of lethals among the sperms of different males. Nishina and Moriwaki have reported nonrandom distribution among sperms belonging to the same male. An experiment made by Dr. Fano was designed to check these unexpected findings. This experiment offered also an opportunity to examine several aspects of the comparative effects of X rays and neutrons, i.e.: (a) how frequently lethals are connected with cytologically detectable minute deficiencies, (b) how frequently lethals are connected with cytologically detectable gross chromosomal aberrations, (c) the relative frequency of recessive and dominant lethals.

Wild-type *Drosophila* males were treated with approximately 600 and 1200 units neutrons, measured with a standard 25-r Victoreen r-meter, and mated partly to ClB virgin females, partly to wild-type virgin females. The treatment was kindly supplied by the Columbia University cyclotron group, under the direction of Dr. J. R. Dunning. Dominant-lethal counts were made on F<sub>1</sub> offspring from wild-type females. F<sub>1</sub> ClB females from ClB parent females were mated singly to their *ec ct<sup>8</sup> v g<sup>2</sup>* brothers and tested for recessive lethals. The maleless F<sub>2</sub> cultures—that is, those carrying a lethal—were further tested

by mating the wild-type females with *ec ct<sup>8</sup> v g<sup>2</sup>* males. F<sub>3</sub> cultures were raised for 62 lethals, to determine the location of the lethal and to obtain salivary-gland cytological preparations.

The dominant-lethal counts have been completed, and show the following results, which are in fair agreement with those of Dempster: The fraction of adults hatching from eggs fertilized by treated sperm was 90 per cent for the controls, 27 per cent for the 600-unit treatment, and 4 per cent for the 1200-unit treatment. According to results reported in Year Book No. 40, it takes respectively about 3000 and 6000 r of X rays to produce the same effect. Assuming that 1 unit neutrons is energetically equivalent to about 2.5 r X rays, it takes about twice as much X-ray energy as neutron energy to produce the same dominant-lethal effect. This factor of 2 is larger than that (1.5) found by Dempster, but the two results are not strictly comparable because Dempster investigated the dosage necessary to induce 50 per cent lethality, instead of 73 per cent or 96 per cent as in the present experiments.

The investigation of the recessive lethals is still in progress, and only tentative results can be indicated. The distribution of lethals does not seem to depart from randomness—a result at variance with the results both of Nagai and Locher and of Nishina and Moriwaki. No lethal has yet been found cytologically to be connected with a deficiency. A large percentage of the lethals (about one-third) seems to be connected with chromosomal rearrangements. This result deviates from the findings on X-ray-induced lethals, but is not unexpected, because the ratio of the frequency of gross chromosomal changes to that of gene mutations is generally higher in neutron-treated than in X-rayed material. The over-all frequency of re-

cessive lethals per unit dose of energy absorbed from radiation has been found to be lower in neutron-treated than in X-rayed material, in agreement with the findings of Timofeef-Ressovsky and Zimmer, already confirmed by Demerec, Kaufmann, and Sutton.

Since neutrons are less efficient than X rays in producing sex-linked recessive lethals in *Drosophila*, when equal amounts of radiation energy are absorbed, Dr. Fano was interested in investigating the theoretical information that can be derived from this comparison. A detailed theory of this phenomenon was developed by Lea, which led to the evaluation of certain important quantities relating to gene structure. Since, however, this theory involved certain very special assumptions, an effort was directed toward estimating its actual significance.

If the production of ionizations along the paths of particles traversing tissue were extremely dense, it is conceivable that all particles passing close enough to the point where a mutation might occur would actually produce it. Under these conditions, the experimental rate of production of mutations would yield a measurement of the cross section of the "sensitive region" which represents the "target" to be "hit" by the particles. This sensitive region may have some significant connection with genetic structures; and therefore the evaluation of its cross section represents a desirable goal. As a matter of fact, no available radiation produces such a high density of ionizations as to fulfill the conditions described above. The theory developed by Lea, however, permits an extrapolation from the data available on the action of neutrons to the ideal case of infinitely dense ionization.

It has been found that this theory is subject to the following criticism: The hypotheses underlying it were selected as

the simplest schema fitting the present knowledge; the factors necessarily neglected might have been expected to average out, so that the results would be approximately correct. On the contrary, it turns out that all the neglected factors act in the same direction, so that the corresponding deviations from Lea's theoretical law add up instead of canceling out. Consequently, Lea's estimate of the cross section of the sensitive region, which is based on an extrapolation, is certainly in error by defect, by an undetermined amount which may conceivably be very large.

#### RADIATION EXPERIMENTS IN *NEUROSPORA*

It has been found by Hollaender and Emmons, working with *Fungi Imperfecti*, that fungi afford suitable material for studying the effect of ultraviolet radiation in producing mutations. The changes produced in *Fungi Imperfecti* could not be subjected to genetical test, however, and it was thought advisable to extend the study to a fungus in which the changes could be tested by being passed through a sexual stage. The ascomycete *Neurospora crassa* was finally chosen as the best available plant for this purpose, for several reasons. The life history of this fungus has been studied in detail by Dodge, who found it to be heterothallic and its sexual reproduction to be subject to experimental control. Lindegren and others have investigated its inheritance and found that Mendelian segregation occurs in the young ascus. Moreover, *Neurospora crassa* produces under certain reproducible conditions a special type of spores, "microconidia" or "spermatia." These spores, by virtue of their small size, uniformity, and probable uninucleate condition, afford favorable material for radiation experiments, as has been demonstrated by Lindegren.

This is a cooperative experiment with the National Institute of Health, in which Dr. M. Demerec, Dr. A. Hollaender, Mrs. M. Houlahan, and Mrs. Eva Sansome are taking part. The ultraviolet experiments are being performed by Hollaender and Houlahan at Bethesda, Maryland, and the X-ray experiments at Cold Spring Harbor; but every effort is being made to keep the conditions of the experiments as nearly comparable as possible.

Microconidia are obtained from the mutant strain *fluffy*, which does not form macroconidia. Fluffy cultures that are not more than three weeks removed from a single-spore (ascospore or microconidium) stage are used, in order to lessen the chance of irradiating spores from a culture that has become heterokaryotic by spontaneous mutation. The spores are extracted in salt solution, filtered through cotton under sterile conditions, centrifuged, and treated in suspension in salt solution. For the X-ray experiment a concentrated suspension of spores in a small vial holding about 1 cc. of suspension is irradiated. Samples of 0.1 cc. are taken for the control and for the different dosages given. Increase in dosage is obtained by increasing the time of exposure. In order to keep the selection of mutants as constant as possible, only the more distinct types are scored as mutants.

As a control on the ultraviolet experiments, 577 untreated spores were isolated, of which 1 was a mutant. In the X-ray experiment, 1 mutant was obtained from 521 untreated spore cultures. The spontaneous mutation rate, therefore, is low, and so far has been of a similar intensity in the Bethesda and Cold Spring Harbor cultures.

In the ultraviolet experiments the wave lengths tested, arranged in order of effectiveness in producing mutation, are 2650, 2537, 2480, 2805, 2380, 2967, 2280 Å.

An average of 4.7 per cent of mutations has been recorded for treatments at 2650, the highest recorded rate being 13 per cent. Nucleic acid has maximum absorption in this region of the spectrum.

In the X-ray experiments a wave length of about 0.3 Å was used and dosages of 2250, 4500, 9000, 13,500, 18,000, and 22,500 r units have been given. The preliminary results indicate a linear increase in mutation rate up to the highest dosage given, as shown below:

Dosage	% mutations among survivors
2,250.....	1
4,500.....	3
9,000.....	5.5
13,500.....	9.8
18,000.....	10
22,500.....	14

There seems to be some evidence that the X-ray treatment at these dosages stimulates the germination of the microconidia. This makes it difficult to detect killing effects of low magnitude. It is reasonably certain, however, that up to 22,500 r units the survival ratio of treated to control spores is more than one-half. It is proposed therefore to increase the dosage until an appreciable amount of killing is obtained.

Of the 119 ultraviolet mutants so far obtained, 11 are "dwarfs," 18 "unstable," 40 "semilethals," and 50 unclassified; of 99 X-ray-induced mutants, 11 are "dwarfs," 14 "unstable," and 3 "semilethal." Of about 40 ultraviolet-induced mutations subjected to preliminary genetical analysis, 1 is possibly a two-gene change, and the others behave as single-gene mutations. Of 23 X-ray-induced mutations, 12 may be single-gene mutants, whereas 11 are definitely not single-gene mutants. Of these 11, 7 show the type of ascospore sterility associated with chromosomal alteration. In



addition, 10 other X-ray-induced mutations gave empty perithecia when crossed with normal.

In the case of the ultraviolet experiments, in which wave lengths with an appreciable effect in inducing mutations are used, the mutation rate increases with increased energy up to a certain point, and then decreases. The X-ray results show a steady increase in mutation rate with dosage, up to the highest dosage given. It is necessary to increase the X-ray dosage until an appreciable amount of killing is obtained, in order to see whether this will be accompanied by a fall in the mutation rate or whether the fall in mutation rate is peculiar to the ultraviolet treatment. The high rate of occurrence of semilethals in the ultraviolet experiments, as contrasted with the X-ray experiments, raises the question whether they are to be correlated with the high death rate in the ultraviolet experiments or whether they are a special effect of the ultraviolet treatment. This question also may be answered by increasing the X-ray dosage.

The suggestion that single-gene mutants are more frequent in the ultraviolet experiments, where they may be almost the only type of mutant, is in accord with expectation.

The unstable or reverting types of mutant raise special problems. Reversion probably results from the overgrowth of "normal" nuclei in a heterokaryon consisting of normal and mutant nuclei. The heterokaryotic condition of the mycelium may be brought about in several ways. It may result from a mixing of nuclei, because a "mutated" and a normal spore are picked up together; or one spore may give rise to two types of nuclei, because only one chromatid of a divided chromosome is affected. Another possibility is that reverse mutation occurs either at the same

or at a different locus. However the heterokaryotic condition is brought about, it results in a unique situation in which natural selection may occur within an organism.

#### GIANT CHROMOSOMES IN MOSQUITOES

Dr. Sutton has studied giant chromosomes in two species of mosquito, *Culex pipiens* and *Aedes aegypti*, eggs of which were obtained by courtesy of Dr. J. Maier, of the Rockefeller Institute, New York.

The giant chromosomes are found in the salivary glands, mid-gut, and Malpighian tubes of the larvae, and persist to the adult stage in the Malpighian tubes. Fairly satisfactory preparations were obtained by using the Malpighian tubes of fourth-instar larvae, pupae, or newly emerged adults, which had been kept at 10-18° C. for a few days, pretreating with acetic-alcohol for 1 minute, and staining with acetic orcein (1 per cent orcein in 45 per cent acetic acid) for about 1 hour.

The giant chromosomes have the characteristic banded structure of the salivary-gland-type chromosomes studied in other Diptera. Both the species studied have a haploid chromosome number of 3. In *Culex pipiens* the individual chromosomes can be followed along their whole length, but in *Aedes aegypti* their continuity is confused by numerous contact points between different chromosome arms and a tendency for the chromosomes to break at these points.

This investigation gives some reason to believe that a comparison of giant-chromosome maps might be useful as a means of distinguishing between different species and subspecies of mosquitoes. Some observations on the development and a brief description of the characteristic features of the giant chromosomes in the two species have been published elsewhere.

### THE THEORY OF CONJUGATED DOUBLE BONDS

The fundamental properties of a large number of compounds important in organic and biologic chemistry are known to be determined by the presence of chains of conjugated double bonds. The nature of the phenomenon of conjugation has been understood theoretically for a number of years, but attempts to develop a detailed theory of the systems of conjugated bonds have not yet progressed very far. A part-time project was undertaken by Dr. Fano, directed toward an understanding of the correlation between the absorption spectrum—that is, the “effective color”—and the length of an aliphatic chain of conjugated bonds. It was found, in the first place, that no essential discrepancy exists between the present experi-

mental and theoretical knowledge on this subject. Further knowledge was gathered on other theoretical questions, among which are the following: (*a*) the effect of electronic exchange on the absorption spectrum, especially for very long chains; (*b*) the difference in properties between chains involving different terminal groups; (*c*) the correlation between the absorption spectrum and the shape of the chain (this correlation allows us to reach certain conclusions on the shape of the chain, a subject about which very little is known yet, either theoretically or experimentally); (*d*) an approach to the theoretical determination of the most stable shape of the chain. This project was, however, discontinued because it was expanding beyond expectation under circumstances which seemed to be unsuitable to its further development.

### MOUSE GENETICS

E. C. MACDOWELL, J. S. POTTER, V. BRYSON, M. J. TAYLOR,  
E. N. WARD, AND T. LAANES

#### SPONTANEOUS LEUKEMIA: FOSTER-NURSING EXPERIMENT

In certain mice the incidence of spontaneous leukemia can be modified by a maternal influence transmitted in the process of nursing and differing according to the strain of the nurse (Year Book No. 40). The surprising thing about this result is that the degree of the influence is not necessarily correlated with the frequency of leukemia in the nurse's strain. That nurses from two low-leukemia strains might differ in their influence was not even conceived when the above experiment was planned, and nurses from the two strains were used for purely practical reasons.

Although attention has been directed primarily to the role of genetic constitution, this result carries such interesting implications that its full confirmation and

interpretation appear to be an obligation. After long deliberation on the minimum requirements for critical evidence, an experiment to test this nursing influence directly has been undertaken; and, with the weaning of all the experimental animals, the initial phase has been completed. The establishment of this long-time experiment is reported in some detail in the interest of cooperation and of avoiding wasteful duplication.

Each litter from reciprocal matings between strains C58 and StoLi was distributed at birth as evenly as possible to foster nurses from each of the three strains C58, StoLi, and Bagg albino (Balb), making six experimental classes. The first milk of the nurses had been taken by other young, but the first milk obtained by the experimental animals came from

their foster nurses. To obtain 416 entirely unnursed young and raise 403 of them successfully with a variety of foster nurses is, in itself, an accomplishment. In order to maintain conditions as normal as possible, all treatment of mothers' nipples and all mechanical devices were avoided; each young was removed from the nest by hand soon after its birth, and held in cotton wool until the last of the litter was born and the foster nurses were ready. To do this, four observers shared a continuous night-and-day watch of the females approaching term and recorded a series of direct observations on parturition behavior and birth times of individual mice. This appears to be the first time that any comparable series of observations has been made on the mouse. Many questions are raised, and a new approach to an understanding of the processes of parturition is suggested.

A contrast appeared in the parturition behavior of the mothers from the two strains. Those from strain C58 concentrated their attention on the job and carried it through with directness and assurance. The fetal membranes were usually broken by the mother in assisting the delivery; after a young was well cleaned, the placenta, which often did not appear till later, would be rapidly and completely eaten. StoLi mothers were generally highly nervous; their attention wandered and the various operations were performed vaguely, in fits and starts. The young might not be completely cleaned and the placenta was seldom more than nibbled about the edges. The young and placenta frequently appeared together, with all membranes intact; the placenta might be somewhat eaten, but the young left unrecognized within the membranes. In such cases, however, the observer would remove the membranes and save the young. The rapidity of asphyxiation in unbroken membranes suggests that the dehiscence

of each placenta must precede the delivery of each young by a very short time, and that the separation of the placenta is the immediate determinant of an individual birth; it follows that the order of dehiscence is regularly from behind, forward. The birth of an entire litter commonly requires a whole hour and occasionally much longer.

A further strain difference appeared in the distribution of births with relation to the time of day. The 28 litters from StoLi mothers were scattered fairly evenly throughout the twenty-four hours, with a slight accumulation at 4 A.M. accounting for 4 more births between midnight and noon than between noon and midnight. Of the 29 litters from C58 mothers, 28 were born in daylight. Starting with one at 4 A.M., the frequencies tended to increase till 5 P.M.; none was born between 6 P.M. and 4 A.M.

At 28 days each hybrid mouse was weaned, marked, weighed, and assigned to a permanent box together with a mouse from each of the other five experimental classes, as far as this was possible with sexes separate. The proportion of males from C58 mothers was less than from StoLi mothers (42 per cent and 54 per cent). The weaning weights provide a measure of the relative success of the different strains of nurses, since the distribution of newborn animals was purely random and since each nurse in a set of three always raised the same number of young (5 in almost all cases). Inequalities within sets of three were removed by adding newborn Bagg albinos where necessary.

The frequency distributions of weights of the 28-day young show unquestionable differences according to the strain of the nurse. The modes for the three distributions lie in ascending 1-gram classes in the order C58, StoLi, Balb; but the means for C58 and StoLi nurses are about 0.5 g.

apart, whereas the means for StoLi and Balb nurses are 2 g. apart. How long these effects of the different kinds of nurses on weight will persist, and whether they have any connection with the nursing influence on leukemia, will appear later.

#### SCREW-TAIL MUTATION

Continued study of mice showing the screw-tail mutation, first reported last year, has added numerous effects to the already extensive list and correspondingly enlarged the range of problems presented. The new problems bear particularly on the determination of skeletal pattern. Each terminal effect offers a clue to the developmental mechanics of a given part. After these specific mechanisms are recognized, determination of the interrelation of their antecedent stages becomes the goal. That they all depend upon one gene indicates some ultimate interrelation. Whether one gene may have more than one action is frequently discussed. It would seem more helpful to ask, At what stage and why do the chains of events leading from one gene to the diverse terminal effects become separated? In such a search the basic problem of differentiation in development becomes identified with the problem of gene action.

Many mutations, when not lethal in early stages, confuse the processes of development so violently that they contribute little toward the analysis of normal developmental processes. The outstanding importance of the screw-tail mutation is due to the moderation of its effects, which therefore become relatable to normal.

The original evidence that this mutation is due to one gene has been amply confirmed by more than doubling the number of mice from segregating pairs (total, 2998 mice); by raising the number of tested normal sibs of screw-tails to

76 (51 heterozygous, 25 homozygous); and by the reappearance of the mutation, intact, from outcrosses into two different strains (one of these crosses was made by Dr. L. C. Dunn at Columbia University). A deficiency of screw-tails, originally reported for males only, now appears to be evenly divided between males and females. This is ascribed to prenatal loss, which becomes selective for screw-tails only in the presence of unfavorable conditions as indicated by increased prenatal mortality of normals. As reported at one time from this laboratory, prenatal mortality of normal mice is lowest in first litters and increases with successive litters. In first litters the expected proportion of screw-tails is found; in later litters the total number decreases and the proportion of screw-tails is reduced until it finally approaches zero. Thus the numerical deficiency of screw-tails shown by the totals depends on the number of litters included from each mother and has little significance. This result does not indicate whether the increasingly unfavorable conditions are due to the number of preceding pregnancies or to the age of the mother, but it does establish a type of variable selective elimination that may very possibly help to explain other cases.

The following newly discovered effects have been studied in an extensive series of alizarin-stained skeletons ranging from 2 days before birth to more than a year afterward:

1. The pelvis is shifted about one vertebra nearer the tail, separating the ilium from the initially first sacral vertebra, which develops as a lumbar vertebra, free from the remaining three sacral vertebrae. The consistency of this effect will permit an embryological study that will bear directly on the interpretation of the variations often found in the number of human lumbar vertebrae.

2. The centra of scattered thoracic and lumbar vertebrae are malformed. They arise from paired, instead of single, bone centers, and as maturity approaches cause sharp spinal flexures, bending outward.

3. The lower jaw is grossly malformed. Even before birth the pattern of the jaw shows a deviation from normal. The distortion becomes progressively more extreme through a large part of life, in connection with the abnormal growth of the teeth.

4. The lower incisor teeth do not grow back into the ramus of the jaw; both upper and lower incisors show defective enamel formation and curve in too sharply. These conditions lead to abnormal wearing of the cutting ends in all cases, and frequently to extreme malocclusion. In old age, forward growth of the incisor through the jaw may become blocked so that the basal end is forced backward through the solid bone, sometimes penetrating its surface. The specific relation between various physiological states and variations in the structure of rat incisors demonstrated by Schour gives the histological study of these teeth great importance.

5. Roots of molar teeth are always feebly developed, and there is only one socket for each tooth instead of a separate socket for each of the three roots. Some of the molars are frequently absent or mis-oriented. The failure of root development, even when a single molar lying on its side is the sole occupant of the tooth cup, indicates a defect within the tooth rather than an abnormality in the growth of the surrounding bone.

6. The top of the skull shows the sagittal sinus permanently uncovered by bone and the coronal suture arching sharply backward with numerous small sutural bones. The modification of these membrane bones, as well as of the jaw, shows that the action of the gene is not limited to carti-

lage bone, or rather cartilage, for no evidence has appeared to indicate that the actual process of ossification is in any way abnormal.

7. From the first deposition of bone the sternum is always a single, unsegmented bone, shorter and broader than normal; the first and fourth to seventh ribs are always attached, but the ends of the second ribs are frequently free, as are the ends of the third ribs occasionally.

Since more questions have been raised than answered by the study of the above effects, further comment will be reserved on all but the sternum, which warrants a fuller account.

The absence of all traces of segmentation not only makes the screw-tail sternum an unparalleled mammalian structure, but also provides a clue to the cause of the normal pattern. Hanson has interpreted the presence of *sternebrae* "as arising from a process of segmentation in response to the demand for as great a measure of elasticity on the ventral side of the animal as is allowed by the more or less flexible vertebral column of the dorsal side. Sutures arising in this manner, as a result of strain, will naturally appear at the weakest parts along the sternum. At the points of attachment of the ribs the sternum is often deeply notched, weakening this region, and here, as expected, occur the lines of division of the sternum into segments or *sternebrae*." The following provides an interpretation more closely related to the actual developmental processes:

In the embryonic sternum of the mouse a persisting growth center is established at the end of each rib. Although the rib end is histologically homogeneous, a gradual differentiation from the most immature to fully differentiated cartilage cells can be followed, passing from the rib end in any direction into the sternum. In screw-

tails, the opposite rib ends are so far apart that the zones of immature cells on the right do not meet those on the left and the oldest cartilage forms a continuous band along the mid-line. Since bone can be deposited only after cartilage is fully mature, the first bone in a screw-tail sternum therefore forms a continuous longitudinal streak. In normal mice, the opposite rib ends are so close together that the zones of immature cells on the right lie in contact with those on the left, breaking up the mature cartilage cells into a series of separate masses. Thus the bone centers form a series of intercostal bands at right angles to the main axis. The fusion of the right and left growth zones leads to the formation of pairs of transverse epiphyseal growth centers, which account for the elongation of the bone centers, with slight increase in width. In screw-tails, on the other hand, the opposite growth zones cannot unite. Each remains practically in contact with the neighboring zones on the same side, so that at birth the sides of the sternum are bordered by cartilage, whose continued growth primarily increases sternal width.

The dependence of growth centers in the sternum upon the rib ends is admirably demonstrated by the variable failure of second and third screw-tail ribs to become attached. Without exception, there

is never a growth center when the rib fails to reach the sternum, and there is always one when the rib is attached. Wherever there is no growth center, ossification quickly extends to the margin of the sternum, which is always narrower at these points.

A further confirmation of this interpretation has been found in numerous non-screw mice, in which the distance of the rib ends from the mid-line is normal but the two members of a pair are not opposite. This may involve a single pair of ribs or several, and the dislocation may be slight or very marked. Correspondingly, either the growth zones meet at an angle, or they do not meet at all and each remains an independent lateral center exactly as in screw-tails. In every case the bone pattern follows the distribution of fully matured cartilage, from sternebrae with crooked ends, to half-size sternebrae staggered in position on the two sides, and, finally, to a continuous wall of troy pattern with segmentation eliminated.

The longitudinal shift in the positions of rib ends leading to a staggered sternum, and the transverse shift leading to the broad screw-tail sternum, are clearly due to very different causes; but the materials of the sternum in the two cases appear to be intrinsically alike, and equally under the control of the ribs.

## ENDOCRINE STUDIES

O. RIDDLE, W. F. HOLLANDER, R. A. MILLER, E. L. LAHR, G. C. SMITH,  
AND H. N. MARVIN

The endocrine organs perform a singular type of "team work" concerned with physical and mental development, and at all life stages they share largely in the regulation of reproduction, growth, bodily maintenance, and behavior. Discovery of the extent to which certain hormones of the pituitary gland share in this "team

work" continues as a central aim in most of the studies described here.

### HORMONAL BASIS OF MATERNAL BEHAVIOR IN RATS

The results of nearly six years of study of this subject by Riddle, Lahr, and Bates have now been analyzed and published.

More than 2900 tests were made with 19 different hormones or hormonal preparations, to determine the role of hormones in the exhibition of unlearned maternal behavior in rats. The more important facts relating to this prolonged study of an "instinct" are summarized here.

Intact albino rats, aged 60 to 70 days, were tested especially for retrieving (that is, carrying young rats, mice, or squabs to a nest) and cuddling responses daily for 10 days. By this means about 22 per cent of "normal reactors" were separated from the nonreactor rats. Thereafter these non-reactors were subjected to hormonal injection for 10 days, with daily records of behavior extending over a further 10-day period. All hormones were tested on a few or many males and females and on castrates of both sexes.

In responding female rats whose mammarys had been developed with estrone during 20 days, the validity of the criteria of response (that is, retrieving and cuddling) was attested by the ability of these rats actually to feed and rear the adopted young.

The maternal drive or instinct was initiated in large or in significant numbers of normal and castrate male and female rats during injection (or pellet implantation) with various hormones: prolactin, progesterone, desoxycorticosterone, intermedin, luteinizing hormone, phenol, and thyroxine; testosterone failed only in normal males. The instinct was not activated by injection with follicle-stimulating hormone, "growth" hormone, adrenotrophin, Prolan, pregnant mare serum, parathyroid extract, or a special extract of thyroid tissue.

Most, but possibly not all, of the effective substances rather clearly exerted an anti-gonad action on the intact rats; the term anti-gonad seems inapplicable to luteinizing hormone, although it too had a tendency to arrest estrous cycles. Castra-

tion alone slightly increased the proportion of "normal reactors," and also increased the effectiveness of all substances capable of exciting the maternal response.

Intact males were as likely as intact females to be "normal reactors," but non-reacting (control) males were more resistant than (the slightly smaller) females to the maternalizing action of all the effective hormones.

Pregnant mare serum, gonadotrophin plus thyrotrophin, and estrone all had much or appreciable ability to terminate well established maternal behavior. These substances do not exert this action in rats deprived of their hypophyses, but they are effective in thyroidless rats.

Removal of the pituitary gland precipitates maternal behavior in approximately 50 per cent of otherwise intact female rats, but not if a decrease of the ovarian function is prevented by injections of pregnant mare serum. Nonreactors following hypophysectomy can, in most cases, be made maternal with either prolactin or progesterone.

In male rats, thyroidectomy alone excites maternal behavior in about 25 per cent of such tests. Male rats not made maternal by this operation seem thereafter more resistant than normal rats to the positive action of prolactin, progesterone, and luteinizing hormone.

The degree of purity or of contamination of the various pituitary preparations used was ascertained. Progressively larger doses of prolactin—6, 18, and 30 units—progressively increased the percentage of rats of all sex types made maternal by treatment.

Recurrent maternal behavior in reproducing rats (the rats tested were not in reproduction) probably does not depend on the several hormones here found to be directly or very indirectly active, but on that one of the group which (*a*) is released in increased amount at the right

time, (b) exerts an anti-gonad action, and (c) then directly or indirectly increases the excitability of the sensorimotor mechanism specifically involved in this instinctive behavior. Though present information is inadequate, the hormone that apparently best fits these requirements is prolactin.

Genetic relationships and differences between mating drive and maternal drive become clearer in the light of results obtained in the present study and in our previous study on broodiness in fowl. The mating drive, or perhaps merely an unexpressed basis for that drive, is apparently a necessary precursor of the maternal drive. It thus appears that the maternal drive or instinct is remotely conditioned by the pituitary hormones (gonadotrophins) which govern the building of egg, sperm, and sex accessories, and is probably precipitated and regulated by another pituitary hormone (prolactin) which is related broadly to the feeding and care of young.

#### PITUITARY HORMONE ACTION IN CARBOHYDRATE AND FAT METABOLISM

Last year's report noted that those extracts from anterior pituitary tissue which have marked "diabetogenic" actions are mixtures of hormones. The extent to which posterior-lobe hormones (and intermedin) contribute to the effectiveness of those mixtures was then almost wholly unknown. This topic has been investigated during the present year by Riddle and Marvin, but the results can be described more conveniently in connection with a summary statement on the entire subject which is planned for next year.

A valuable aid to study of the hormones contained in effective extracts was rendered by Drs. E. M. K. Geiling and G. Chen, of the Department of Pharmacology, University of Chicago. Utilizing their

newly developed methods for the assay of intermedin (melanophore hormone), they have examined our standard-type pituitary preparations and determined that their content of melanophore units is as follows: whole anterior pituitary extract (no. 650), 1760 units; gonadotrophin plus thyrotrophin (no. 630), 2000 units; prolactin (no. 657), 94 units; prolactin (no. 861), 100 units; a "mother" fraction (no. 804) from which ammonium sulfate fractionation is done (see last year's report), 340 units; whole posterior pituitary (alkaline) extract (no. 779), 2940 units; whole extract of beef muscle (no. 681m), 0 units. This information makes it possible to estimate or to exclude the effects of intermedin on the sugar, glycogen, fat, and ketone values obtained following the use of our standard preparations.

*Gross differences in response of the liver to first and later daily dosage with insulin and prolactin.* Studies on this topic were largely completed by Riddle and Opdyke prior to the present year, but the results were reported only in part last year. Pigeons survive huge doses of insulin, and it is known that a course of 4 to 7 daily injections of prolactin doubles the weight of their livers. Young pigeons were given from 1 to 5 daily injections of insulin or prolactin, and differences between the response to a first and to subsequent injections were measured in the case of liver glycogen and fat, ketonemia and glycemia. All values were obtained at the end of a 24-hour fast. A first treatment with insulin (70 units per kilo of body weight) was found to increase liver fat by about 160 per cent, but under further dosage the fat falls to or below the normal values. First, but not later, insulin injections produce ketonemia (at 10 hours after injection). Twelve hours after a first injection the blood sugar is decreased by 25 per cent,



but 12 hours after a second daily injection it is increased by 50 per cent in both normal and hypophysectomized birds. Twenty-four hours after a first injection of prolactin the percentage of liver glycogen is increased, but third and later injections neither maintain nor produce this increase; in these tests, and during at least 6 days, total liver fat is increased essentially parallel with increase of hepatic tissue.

Though the nutritive state of these animals is affected by temporary and prolonged dosage with either insulin or prolactin, these results mainly reflect the ability of the first dose of these hormones to set a new level of functioning in one or another regulatory organ (adrenal, pancreas, pituitary). These studies, therefore, contribute to an understanding of the normal mechanism concerned in the regulation of carbohydrate and fat metabolism.

*Effects of anterior pituitary preparations and insulin on islet cells of the pigeon pancreas.* There is uncertainty concerning the number and the cellular sources of hormones secreted by the pancreas, and also uncertainty concerning functional interrelations between pituitary and pancreatic hormones. Other current studies, particularly those on carbohydrate and fat metabolism, have supplied an abundance of variously treated pancreatic tissues which are suitable for a clarification of some of the above-mentioned problems. This material has been utilized during the past two years by Dr. Miller, with the results stated below.

Three types of islet cell are identifiable in the pigeon pancreas. In young Carneau pigeons fasted 10 days, and in pigeons whose pituitary glands have been removed, the beta cells seem inactive or degenerating; only slight changes in alpha and delta cells occur. Force-feeding of hypophysectomized pigeons maintains a normal appearance in the three types of cell. Prolactin, overfeeding, partial pancreatectomy,

and some preparations of corticotrophin all stimulate beta cells; gonadotrophin and thyrotrophin have no effect. Large doses of insulin induce a marked atrophy of beta cells.

Four series of pituitary extracts obtained by fractional precipitation with ammonium sulfate (whose effects on glycemia, ketonemia, and liver fat were fully described in last year's report) were tested in normal and hypophysectomized pigeons and found to induce degenerative changes in beta cells. Stimulation of delta cells was observed with certain fractions from 10 hours after a single injection to 24 hours after the last of 7 daily injections. Substances stimulating delta cells are most concentrated in material precipitated at one-third saturation (fractions B and C) and tend to be insoluble on dialysis. There is an association between the delta-cell-stimulating action of these fractions and their ability to increase liver fat. Limited delta-cell stimulation occurs in pigeons treated with prolactin and with insulin. The actions of ammonium sulfate fractions on delta cells are not directly associated with any particular one of the hormones known to be present in these impure preparations.

The granules of alpha cells are markedly depleted by insulin and less markedly by some ammonium sulfate fractions and by corticotrophins.

*The cytology of the pigeon adrenal cortex in experimentally induced atrophy and hyperactivity.* The activity of the adrenal cortex is at least partly controlled by the pituitary gland, and one or more hormones produced by the cortex are known to play a part in carbohydrate metabolism. These facts led Miller and Riddle to a careful study of the cellular changes that accompany hormone production in cells of the adrenal cortex. The appearance of the Golgi apparatus, mitochondria, lipoid,

cholesterol, and water-insoluble ketones in adrenal cortical cells of young (1.9 to 2.4 months old) normal Carneau pigeons was compared with the cytological picture in experimentally induced atrophy and hyperactivity. The conclusions now drawn from this study complete and notably supplement the related studies described in earlier reports.

Mitochondria seem to be involved in the formation of cortical hormone(s) which, together with a possible precursor (cholesterol), is present in the lipoid droplets. The rate of formation of lipoid normally exceeds the demands of the organism, and storage results. The Golgi apparatus may transform lipoid into the final product. In stimulated adrenals a marked proliferation of mitochondria maintains the rapid formation and excretion of lipoid; cholesterol, lipoid, and water-insoluble ketones are diminished. Following hypophysectomy cortical activity is limited to a few peripheral cells, and in a few adrenals these peripheral cells give little or no indication of activity. Injections of cortical hormone into unoperated pigeons cause atrophy of the cortex; similar injections into hypophysectomized pigeons further decrease the weight of the gland and suppress the activity of cells in the peripheral zone. In hypophysectomized pigeons, formaldehyde and several nonpituitary hormones produce cytological changes in the cortex which are similar to those resulting from corticotrophin. Adrenal cells of normal nestlings and adult pigeons show greater activity than do those of young preadolescent pigeons.

*Alleged thymus mediation of pituitary function.* A series of papers published in 1940 by Bomskov and co-workers in Freiburg reported the preparation and the extensive investigation of an ether-soluble extract of the thymus. Such an extract was said to be "diabetogenic" in rats, guinea

pigs, and pigeons, in that it showed marked glycogenolytic and hyperglycemic actions. Those investigators further claimed that a diabetogenic-thymotrophic fraction obtained by them from the pituitary gland is identical with "growth" hormone, and that physiologic effects of the latter pituitary substance are thus also mediated by the thymus hormone. The strong claims of these workers to a resolution of problems in which this laboratory has long been interested led Wells, Riddle, and Marvin to repeat the Freiburg studies. With none of three preparations of an ether-soluble extract of calf thymus was it possible to confirm the reports of the Freiburg group. Neither glycogenolytic, glycemic, nor ketogenic activity was observed in rather extensive tests on rats and pigeons. No significant leucocytosis was obtained in rats. Short-term tests showed no appreciable effects on bodily growth in young rats, chicks, or pigeons.

*A technique for thyroidectomy in the pigeon and the early effect of thyroid removal on heat production.* Investigations frequently require the use of birds completely deprived of their thyroid tissue, and the technique hitherto employed in this operation on pigeons was in some respects unsatisfactory. Marvin and Smith have developed a technique for a two-stage operation that avoids the immobilization of the crop ("crop binding") which is frequent when other methods are used. Elimination of this effect increases the usefulness of the operated birds for the various studies on metabolism that require thyroidless birds. The effect of the operation on the respiratory metabolism is almost immediate. The basal heat production of 8 birds was apparently somewhat depressed at 4 to 5 days after the removal of one thyroid, and in 13 birds the basal metabolism was  $-20$  at 7 to 8 days after complete thyroidectomy; in another group of 7 pi-

geons a value of  $-27$  was obtained at 6 to 46 days after complete thyroidectomy. Almost all birds survive this operation, and the technique permits a rapid and usually a complete removal of the thyroids of pigeons.

#### ADRENAL CORTICAL HORMONE AND PROLACTIN

*The relation of hormones of the adrenal cortex to growth.* During the past few years this laboratory has directed some effort to an analysis of the means by which the anterior pituitary gland promotes and regulates growth. In tests made with mammals, other laboratories have essentially failed to find that adrenal cortical hormones—all probably produced under stimulation by pituitary corticotrophin—support or increase body weight in hypophysectomized animals. Using pituitaryless pigeons, Miller and Riddle have obtained positive results with cortical extract, and particularly with desoxycorticosterone acetate; moreover, this effect on body weight has been shown to be additive to the support afforded by minute doses of prolactin. The present experiments represent short-term tests, and they are more directly concerned with prevention of the large loss of body weight that follows removal of the pituitary, but their bearing on the problem of growth is evident. Parts of the data are shown in figure 2.

After removal of the anterior pituitary gland from groups of Carneau pigeons aged 7 weeks, the birds were injected daily for a period of 10 days, then sacrificed, and the weights of various organs obtained. Operated birds given no treatment during this 10-day period show an average loss of 21 per cent of their body weight. Groups of operated pigeons injected with an extract of adrenal cortex lost 13 and 14 per cent of their original

weight. When these birds were injected with desoxycorticosterone acetate at optimal dosage, 2 to 3 mg. daily, this loss of weight was reduced to 6 per cent; doses larger than 3 mg. were toxic. When this substance and testosterone propionate were injected together, the male sex hormone showed no ability to assist growth or to maintain body weight. Groups injected daily with 1 mg. desoxycorticosterone lost 10 per cent, and those injected daily with 1 unit of prolactin lost 8 per cent, of their preoperative weight. When these quantities of the two hormones were injected together, the birds regained all the weight lost as an early or incidental result of the operation (see fig. 2) and at killing were 1 per cent heavier than at the start of the test. Preliminary tests, which are subject to further confirmation, have suggested that the injection of only 0.005 mg. of thyroxine in addition to 1 mg. of desoxycorticosterone and 1 unit of prolactin increases this gain in body weight to 4 per cent. This gain equals the average gain shown by animals that retain their pituitaries and are subjected to no operation during this same 10-day period. These hormones, and mixtures of hormones, also maintained or increased the weights of the intestine and liver, but they had no similar action on thyroids, testes, and adrenals.

The hormones that replace the effect of the pituitary in the maintenance or increase of body weight stimulate appetite and food consumption notably, and they apparently enable pigeons to utilize their food more efficiently. Extract of adrenal cortex and desoxycorticosterone also markedly increase the intake and output of water. Determinations of the water content of breast muscles and livers of treated and control birds show that the support of body weight by these hormones is not accomplished by, and is not a consequence of, the hydration of these tissues.

Smaller numbers of tests of the action of cortical hormone and prolactin in adrenalectomized pigeons support the conclusion already presented. Uninjected adrenalectomized pigeons lost 12 per cent of their preoperative weight in 10 days. Daily dosage with 50 units of prolactin caused a

*Local crop-sac or micro method for assay of prolactin.* Two years ago it was noted that several nonpituitary substances, when injected intracutaneously over the crop, stimulate cell division in the lining of the pigeon's crop sac. Those observations indicated that certain precautions

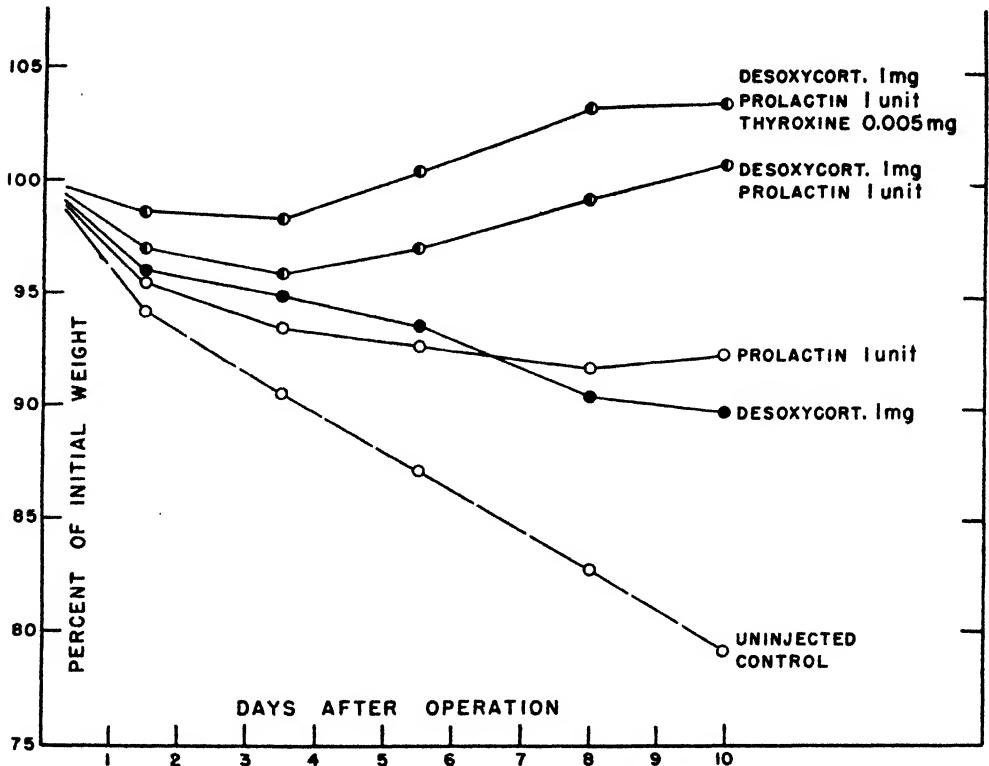


FIG. 2. Graph showing support of body weight in groups of pigeons (10 to 38) by daily injections of desoxycorticosterone acetate with and without the addition of 1 unit of prolactin. The data are for the 10-day period immediately following the removal of the anterior pituitary gland of Carneau pigeons aged 7 weeks.

significant temporary increase in weight, but at the end of 10 days the animals (some near death from lack of life-maintaining cortical hormone) had lost about 8 per cent of their preoperative weight. Birds of one group injected daily with extract of adrenal cortex together with 50 units of prolactin increased their body weight by 9 per cent in 5 days.

must be taken in the use of this method for the micro-assay of prolactin. At that time, however, it was not possible to account for the disturbing fact that two seemingly valid criteria of crop-sac stimulation were in frequent disagreement. Thus, at 24 or 48 hours after an injection many of the crop sacs examined by transmitted light seemed thickened and rugose

(positive response), though actual counts of dividing cells (after colchicine) showed no increase in the rate of cell division. During the present year Lahr and Riddle have clarified this difficulty by showing that visible thickening and rugosity may result (and persist for 48 hours) from increased cell divisions strictly limited to short periods (2 to 7 hours) following the injection. An entirely normal rate of cell division in an epithelium that was definitely thickened as a result of an earlier treatment involves, therefore, no real contradiction. It was shown, further, that leukotaxine (1.0 mg.) is one of the substances that temporarily (4 and 7 hours) stimulate mitoses and also tend to show visible stimulation (positive response) at 24 or 48 hours after the last previous injection. This demonstration that a "wound substance" shares in this response, and that its action is immediate and of short duration, has special significance; it supports the view that the entire list of nonspecific substances may exert their action on the crop epithelium as a secondary result of their excitation of "wound substance" in or near the lining of the crop. In contrast, prolactin is effective when injected at sites far removed from the crop sac; its specific ability to cause proliferation of crop epithelium wholly independent of "wound substance" therefore seems unquestionable.

#### BREEDING OPERATIONS AND STUDY OF ENDEMIC GOITER IN PIGEONS

In February 1942, Dr. Hollander became associated with this group, more especially to assist in the genetic analysis of breeding operations conducted by Riddle on doves and pigeons during more than twenty years, and in the preparation of this material for publication. In addition, certain genetic and physiological tests on some

segments of this large bird colony are continuing with his aid or supervision.

Adequate analysis now clearly shows that the "scraggly" pigeon character, which has been extant in the colony since its inception, is a simple recessive trait. The ratios obtained in summaries of the four possible types of mating show a moderate deficiency in the scraggly classes, but this is interpreted as evidence of a higher mortality of scragglies than of normals during the early period (to 10 to 14 days after hatching) when scragglies cannot easily be distinguished from normals. Plumage and skin defects, and an abnormally high rate of heat production, definitely distinguish the scragglies from normal birds.

Outcrosses of females of our hermaphrodite-producing strain of pigeons to males of normal stocks have produced a high percentage of sons having rudimentary left oviducts, but no ovotestes have appeared. On the other hand, hermaphroditic or partially hermaphroditic males (those merely with left oviducts) outcrossed to females of normal stocks have given thus far only normal offspring.

The apparent relation of endemic goiter in pigeons to embryonic weakness has led to an investigation of this subject. Thyroid enlargement, up to 250 times normal size, has been observed occasionally in our pigeons over a period of many years. The study is still in progress, but it is clear that the goitrous tendency is most marked in old birds and among pigeons of the large breeds; it is rare in the ringdoves. It has been established that occurrence of enlarged thyroids in reproducing female pigeons is highly correlated with poor hatchability, late hatching, and the production of weak offspring. Reference to the fact that eggs from goitrous female pigeons require 2 to 3 extra days of incubation was contained in the report for 1929-1930

(Year Book No. 29). It is now found that the offspring of goitrous mothers also usually have large thyroids at hatching.

Preliminary tests for effects of supplements of potassium iodide in the mother's diet indicate that her enlarged thyroids regress toward normal size within a few weeks, and that there is coincident improvement in the hatchability of her eggs and the vigor of her offspring. The effect of this treatment on the heat production

of these adult birds is not yet adequately determined, but Smith has shown that short-term administration of larger doses of the iodide to groups of young pigeons increases their rate of heat production by 5 to 19 per cent. Extremely goitrous pigeons have shown clear evidence of deficiency of thyroid hormone; their ability to regenerate feathers spontaneously from plucked areas is greatly decreased and their basal heat production is diminished.

## ANTHROPOLOGY AND HUMAN GENETICS

MORRIS STEGGERDA AND CATHERINE SHAFFER

### ANTHROPOMETRY

*Child development.* It is known that some human populations are taller and heavier today than they were in years past. For example, students from some colleges are taller and weigh more on the average than did their parents when they attended school. United States soldiers are said to be heavier now than were the soldiers in the First World War, and they, in turn, were heavier than those of the Civil War. This tendency has been reported from various parts of the world and is often accounted for by better living conditions. Meredith, reporting on data from Iowa school children, showed that mean statures and weights for children in 1930-1937 were respectively  $\frac{3}{4}$  inch and 3 pounds greater than those from the preceding decade. Similarly, data from the schools of Hagerstown, Maryland showed an increase in weight for children measured in 1940 as compared with those measured in 1933.

When the present study on the growth of children of different races began, in 1931, it concerned the growth of individuals and did not deal with mass statistics. In 1941, however, in view of the previously mentioned trends in growth, a large

number of Dutch white and Navajo children were measured for stature and weight. These data were averaged for each age, sex, and race. By combining all the Dutch white children measured in 1931 to 1934 and the Navajo children measured in 1932 to 1934, a sufficient number was obtained for comparison with the 1941 groups. The results obtained are summarized briefly in table 1 and in figure 3.

It will be noticed from table 1 that, for every age, the 1941 children are taller than those of 1931-1934. Most often the differences are not statistically significant. The trend, however, is definite. The differences in the 11- and 16-year groups are more than three times the probable error of the difference, and may be considered statistically significant. A weighted average of the differences shows that the children of 1941 are 13.63 mm. taller than those of the 1931-1934 group. For weight the same condition exists in that, for every age, the 1941 children are heavier. The weighted average of differences here is exactly 5 pounds. In nine of the twelve age-group categories the differences are significant, being more than three times the probable error.

The data for the Dutch white females are practically identical, showing the weighted average of stature to be 12.54 mm. greater for each age in 1941 than in

the results for the males are similar. It will be noticed that the height of the 1941 Navajo children is greater for each age than that of the 1932-1934 children. Simi-

TABLE 1

MEANS AND PROBABLE ERRORS FOR HEIGHT AND WEIGHT OF DUTCH WHITE MALE CHILDREN MEASURED IN HOLLAND, MICHIGAN, 1931 TO 1934, AS COMPARED WITH OTHERS MEASURED IN 1941

AGE	1931-1934			1941		
	No.	Stature (mm.)	Weight (lbs.)	No.	Stature (mm.)	Weight (lbs.)
6...	100	1151.40±3.11	44.80±0.35	88	1162.96±3.65	45.91±0.43
7...	100	1218.20±3.21	50.25±0.43	94	1229.58±3.79	52.87±0.63
8...	100	1267.40±3.82	55.00±0.42	95	1274.64±3.78	57.56±0.55
9...	100	1324.20±3.87	62.50±0.54	99	1335.46±3.84	63.92±0.57
10...	100	1375.00±4.37	67.10±0.70	107	1385.14±3.61	70.35±0.77
11...	100	1412.00±3.80	73.05±0.71	105	1431.90±3.95	76.88±0.81
12...	100	1481.20±4.52	84.60±1.19	104	1483.26±4.67	86.16±1.01
13...	100	1528.00±4.86	88.40±0.97	110	1534.36±4.75	94.23±1.09
14...	100	1601.40±5.70	103.10±1.22	57	1619.48±7.97	111.63±1.75
15...	100	1665.00±6.05	111.85±1.43	79	1677.34±7.00	122.63±1.63
16...	68	1690.88±7.10	122.50±1.69	97	1731.86±5.47	136.16±1.49
17...	37	1733.78±6.68	130.34±1.70	90	1754.22±5.08	139.11±1.52

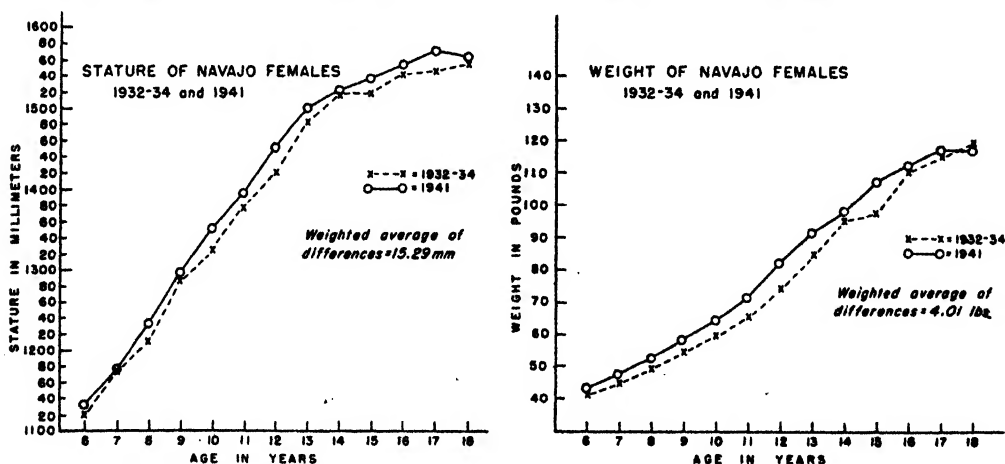


FIG. 3. Height and weight of Navajo female children measured in New Mexico and Arizona in 1932 to 1934, as compared with others measured in 1941.

1933, and that of body weight 4.57 pounds greater.

For the Navajo children, the data are shown in the form of graphs (fig. 3). For these we show only the females, although

larily, the graphs for weight indicate heavier children in 1941 than in 1932-1934. The weighted averages of differences for stature indicate an increase of 15.29 mm. and, for weight, 4.01 pounds. Figures for

male Navajos were 12.07 mm. and 4.67 pounds, respectively.

The unique feature of these data is that the children were all measured by one person using a similar technique. It cannot be said that Dr. Steggerda's technique varied in this decade, for properly balanced scales were used and the same deductions were made for the minimum clothes worn during the measuring. As for the technique for taking stature, he vouches for the similarity of his technique for these two periods.

Believing that still more data would prove helpful, Dr. Steggerda obtained from the Department of Physical Education at Tuskegee Institute, Alabama, the heights and weights of Negro women taken by the teachers during the past decade. The data for 1934 were compared with those for 1941, and the results obtained indicated the same trend as that found for the Dutch and Navajos. The Negro data are not arranged according to age, since the age limits were approximately the same (17 to 23), but rather one mean was made for stature and another for weight for the two periods. The results are summarized as follows: Stature, 1934,  $1609.20 \pm 2.53$  mm.; 1941,  $1625.38 \pm 2.24$  mm. Weight, 1934,  $118.47 \pm 0.73$  pounds; 1941,  $121.99 \pm 0.69$  pounds.

No positive data are available to explain these increases in height and weight during this very short period of time. We are aware of the general increase in height and weight of many human populations. We know that the depression did affect the food intake of the Dutch whites in Holland, Michigan. We know, also, that the Navajo Indians enjoy better living conditions and more healthful surroundings now than they did 10 years ago. We know, further, that the entire population consumes more vitamins and is more conscious of them today than 10 years ago.

But which factors determine the increase has not been ascertained. The present purpose is merely to add these data to the literature with the hope of a future explanation.

*Comparative measurements of Negro and white men.* In 1938 the physical proportions of 100 Negro women from Tuskegee Institute, Alabama were described and compared with a series of white girls from Smith College who were also measured by Dr. Steggerda. During the present year a similar set of data involving 100 Negro men from Tuskegee Institute has been analyzed and compared with data on white college men supplied by Professor H. H. Plough from Amherst College.

The average stature of the Tuskegee men was 1749 mm., or 30 mm. greater than that of the large Negro army series of Davenport and Love, and 44 mm. greater than that of a group of unselected Negro males supplied by Herskovits. The Tuskegee Negroes were 26 mm. or approximately 1 inch shorter than Amherst College men, although their weight was the same, namely 70.06 kg. In sitting height the Tuskegee students averaged 33 mm. less than the Amherst students, a fact which indicates the relatively short trunks and long legs of the Negro boys. This is shown also in the relative sitting height, which for Negroes is 50.9 per cent as compared with 52.1 per cent for Amherst whites; the average trunk height of the white students, therefore, is relatively greater than that of Tuskegee Negro students. This finding is not at all new, but is included as an additional record.

In biacromial breadth, i.e., width of shoulders, the Tuskegee Negroes averaged 410 mm., or more than the Amherst students, who averaged 402.5 mm.

In span or length of the outstretched arms, the Tuskegee men averaged 1847



mm., or over 2 inches more than the Amherst men. This difference in arm span is more apparent when relative span is considered, namely, arm stretch divided by stature. This for the Tuskegee Negroes averaged 106.2 per cent and for the Amherst students 101.2 per cent, a difference which is highly significant.

In this study of Negro males, 60 direct and derived measurements were considered.

*Anthropometric technique.* It has long been recognized that the technique of anthropometry varies greatly among anthropometrists. A problem was devised whereby a number of anthropometrists were to measure the same subject in order to determine the extent of the variations for different dimensions. It was planned also to supply the anthropometrist with only one direction, namely, to measure the subject with the technique familiar to him, selecting the dimensions that he deemed important. In this way the relative importance of each dimension as considered by the leading anthropometrists could be ascertained. The subject and Dr. Steggerda visited the laboratories of the twenty-one anthropometrists who participated in this experiment.

The average number of measurements taken by the twenty-one investigators was 24. One took as few as 16, and another took as many as 45 dimensions. Only 18 were taken by more than one-half of the twenty-one investigators.

These 18 measurements showed both uniformity and differences in technique, as was evidenced by the variability of the distributions. Stature, sitting height, head length, head breadth, and nose breadth showed sufficient uniformity to warrant the conclusion that no great differences in technique were involved.

The rest of the 18 measurements, however, were obviously taken with dissimilar

techniques. Intercrestal breadth varied from 272 mm. to 324 mm., a difference of more than 2 inches. Nearly the same difference was found for biacromial breadth. The measurements for hand length varied as much as 20 mm., and measurements of the face also showed wide variations. Especially in the measurements involving the location of the nasion were the results too variable for accuracy.

A number of other inconsistencies of technique became apparent. For example, in locating the landmarks on the shoulders and hips there was no uniformity of pressure exerted and no apparent agreement as to whether the points of measurement should be the bony landmarks or the outside contours. Also, there was little uniformity in the instruments used for body measurements. All agreed, for example, that head height was an important measurement, yet four different instruments were used by the eleven investigators who took this measurement.

The experiment definitely showed a need for clearer directions for taking shoulder width, chest transverse, chest A.P. (anteroposterior), intercrestal breadth, nose length, hand length, and hand breadth.

It was recommended to the Society of Physical Anthropologists that a committee be appointed to make the necessary recommendations for the development of uniformity in the study of anthropometry.

#### CROSS SECTIONS OF HUMAN HEAD HAIR

In Year Book No. 39, a unique method was described for cross-sectioning a large number of human head hairs at one operation. In last year's report a summary was given showing the effects of race, sex, age, and the region on the shaft where the section was made, upon the size and shape of the hair. During the year more work was done relative to the change in size and shape of head hair with age.

Fifty Maya Indian females and 53 males, ranging from the age of 1 to 69, were selected. Approximately 75 hairs from each individual were sectioned and measured. The hair was cut close to the scalp in the same region of the head, and the sections were all made 20 mm. from the original cut. Both the males and the females were put into 10-year age groups, and the means and standard deviations with their probable errors were calculated for the area and for the index. The results are given in table 2.

males in three age groups, and greater in four.

Work on the hair sections is being continued, with special reference to the manner of hair growth in and from the follicles. Histological sections have been made from both Negro and white scalps. Cross sections of hairs in the dermis seem to indicate the same racial characteristics that they demonstrate in hair outside the scalp. Correlations are being made of such cross sections. Information is also being gathered on the shape of the hair follicles,

TABLE 2

MEANS AND PROBABLE ERRORS FOR AREA AND INDEX OF CROSS SECTIONS OF MAYA HEAD HAIR FROM INDIVIDUALS OF VARIOUS AGE GROUPS

AGE GROUP	AREA ( $\mu^2/100$ )		INDEX	
	Males	Females	Males	Females
0-9.....	27.09 $\pm$ 0.35	27.48 $\pm$ 0.82	88.49 $\pm$ 0.22	88.93 $\pm$ 0.33
10-19.....	37.82 $\pm$ 0.32	33.57 $\pm$ 0.27	83.61 $\pm$ 0.23	82.63 $\pm$ 0.23
20-29.....	40.62 $\pm$ 0.47	40.57 $\pm$ 0.58	83.47 $\pm$ 0.37	80.94 $\pm$ 0.44
30-39.....	39.67 $\pm$ 0.35	35.15 $\pm$ 0.31	80.61 $\pm$ 0.30	84.29 $\pm$ 0.25
40-49.....	33.17 $\pm$ 0.42	35.98 $\pm$ 0.36	80.62 $\pm$ 0.31	77.71 $\pm$ 0.35
50-59.....	39.75 $\pm$ 0.44	32.32 $\pm$ 0.38	81.50 $\pm$ 0.35	83.82 $\pm$ 0.34
60-69.....	32.46 $\pm$ 1.13	29.63 $\pm$ 0.37	80.06 $\pm$ 0.67	85.46 $\pm$ 0.38

From this table it is apparent that Maya hair is smallest in early childhood and increases rapidly in both males and females to a maximum in the 20-29 age group. Thereafter the area tapers off, except for an extraordinary rise in the male 50-59 age group. In the majority of age groups, the females had smaller hair. On the other hand, the index drops considerably, indicating a more elliptical cross section in progressing from the average age of 5 to that of 15. In the males this diminution continues to the average age of 35 and then remains fairly constant thereafter. The female trend is rather irregular, with peaks in the groups 30-39, 50-59, and 60-69; the index is less than that of the

with the aim of correlating this with the final hair shape.

### TEETH

Differences and similarities in the teeth of four racial groups have been reported in previous Year Books. Differences have been demonstrated in the amount of caries present and also in the eruption time of teeth. The races were similar in the order in which teeth appeared in the mouth. At present an attempt is being made to correlate dental development with the growth of the individual. The preliminary findings indicate a very low correlation, almost negligible, which means that although tooth eruption correlates with

chronological age, it does not necessarily correlate with general body development. Thus, because an individual grows fast in body size it does not mean that his dental development will necessarily be earlier. For this problem, means have been established for various body proportions for each age and sex, as well as the mean eruption time for each tooth for each age and sex, and the above-mentioned correlations are now being made.

### SOUTH AMERICAN INDIANS

In 1932 Dr. Steggerda made a survey of statures and cephalic indices of the various Indian tribes of North America. Two years ago a survey was begun, at the request of the Smithsonian Institution, to determine the known anthropometry of South American Indians; and, at present, this study has progressed to include some anthropometrical data on more than 80 different tribes. For some tribes several investigators have contributed data, so that the study includes 132 different investigations on the 80 tribes considered. The general observations deduced from this survey reveal that:

The South American Indians are, on the average, shorter in stature than the North American Indians. Fifteen tribes of those studied show a stature below 155 cm. The greatest number of tribes (43) is found in the stature group 160-164.9 cm. There

were 2 tribes in the group representing statures of from 180 to 184.9 cm., namely the Onas and Tehuelches, both located in the southernmost part of the South American continent.

The range in stature is greater in the South American Indians than in those of North America. In other words, the shortest and the tallest American Indians are to be found in South America. Among the tribes belonging to the shortest stature group we find individuals averaging as low as 145 cm.; on the other hand, the high-stature group includes mean body heights of 184 cm.

Regarding the cephalic index, only 2 tribes show an index under 76 per cent, namely the Chipaya and Alacaluf, the lowest cephalic index having been found in a group of Chipaya males that showed an average of 72.8 per cent. Percentages of 84 and over were found to exist in 13 different tribes, with the Conibos showing the highest index, 91.36. Other body dimensions are being listed for further study, and contour maps are being made to show the geographical location of the various Indians relative to their body proportions.

The review also concerns the hybrid populations of South America. Much is being learned regarding cultural traits, food habits, growth, and development, all subjects which have been studied in detail by Dr. Steggerda for the Maya and Navajo Indians of North America.

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## NUTRITION LABORATORY

*Boston, Massachusetts*

THORNE M. CARPENTER, *Acting Director*

The research program of the Nutrition Laboratory has been affected by the war situation more seriously this year than last year. The defense investigation that was carried on during 1941 was completed on January 1, 1942. Since that time another war study has been started, and again the training of the personnel and the equipment at the Nutrition Laboratory have proved of great aid. Fortunately this latest investigation is resulting in the acquisition of information that will be of scientific value as well as of immediate practical application, for it fits in with the Laboratory's program in opera-

tion since its beginning, namely, the study of phases of the physiology of respiration in relation to respiratory exchange. Some preliminary work has also been done in the way of orientation on several projects that have developed as a result of previous studies in the Laboratory's research program. It is gratifying that, notwithstanding the pressure of the requirements for war research, information is being acquired that will make it possible ultimately, when opportunity offers, to carry on further studies related to the principal objectives of research.

### STAFF NOTES

At a meeting of the American Chemical Society at Atlantic City, New Jersey, on September 9, 1941, Dr. T. M. Carpenter presented a paper (jointly with V. Coropatchinsky) entitled "A modified Noyons thermic diaferometer for respiratory gas analysis." This paper was part of a symposium on "New analytical tools for biological and food research." On October 10, 1941, Dr. Carpenter was appointed a member of Section B7c in Division B of the National Defense Research Committee. This superseded his appointment as a consultant in Section L-12 in Division B. On February 6, 1942, he attended as a delegate from the Nutrition Laboratory the Massachusetts Nutrition Conference, which was held at the Massachusetts Institute of Technology in Cambridge, Massachusetts, at the request of Governor Leverett Saltonstall.

For the meeting of the Federation of

American Societies for Experimental Biology, held in Boston on March 31 to April 4, 1942, Dr. Carpenter was Chairman of the Entertainment Committee and Robert C. Lee served on the Personnel Committee.

Dr. Carpenter's annual lecture on basal metabolism was given to the students of the Harvard Medical School on February 27, 1942.

Throughout the year Dr. Carpenter, Robert C. Lee, George Lee, and V. Coropatchinsky have devoted almost their entire time to national defense projects.

Mr. Basil James, a member of the Nutrition Laboratory staff since 1929, resigned on November 19, 1941. Miss M. Joan Blakely acted as laboratory assistant in the metabolism tests on diabetic patients at the New England Deaconess Hospital from June 9, 1941 to November 15, 1941. Miss Jeannette F. Rayner was appointed on

December 8, 1941 to take her place, and has been carrying on the metabolism measurements full time ever since. Miss Charlotte P. Curtis served as laboratory technician, in connection with urine analyses,

from December 3, 1941 to February 14, 1942, and Miss Mary A. Crowley served in the same capacity from March 2, 1942 to May 29, 1942.

## INVESTIGATIONS IN PROGRESS

*Relation of the rabbit's body composition to its basal metabolism.* The chemical analyses of the rabbits that were used for the determination of the basal metabolism of this animal species have been completed. R. C. Lee has had charge of these analyses and has been assisted by G. Lee.

*Carbon dioxide in outdoor air.* The possibility that there are variations in the carbon dioxide content of atmospheric air, particularly at the earth's surface, has been of immense interest and the object of many studies especially in relation to different atmospheric conditions and to plant growth. With the gas-analysis apparatus and other apparatus thus far available, little evidence has been obtained that there are significant changes in the carbon dioxide content of outdoor air from day to day. The modified Noyons diaferometer, the development of which was completed last year and a description of which was published this year (see p. 222), gives opportunity for much more refined and accurate determinations. During a period of cessation of activities in defense work, preliminary observations were made with this apparatus in a systematic way, to establish whether there are variations in the carbon dioxide content of outdoor air from day to day and at different times of the day. An attempt was also made to construct a volumetric gas-analysis apparatus that would be capable, theoretically, of measuring the carbon dioxide content of outdoor air with an accuracy of 0.001 per cent. After intense effort, however, it was found impossible to obtain results of

this degree of accuracy with this type of apparatus. In a volumetric gas-analysis apparatus a number of factors play a role, namely, changes in barometric pressure, changes in temperature, and changes in the degree of saturation with water vapor. Because of these factors apparently there are physical limits beyond which it is not possible to refine this type of apparatus and have it function accurately to give reliable results. The Noyons diaferometer can be modified with suitable shunts in the galvanometer system so that the carbon dioxide content of outdoor air samples can be determined to within 0.0003 per cent. Observations with this diaferometer have shown that there is some variation in the carbon dioxide content of outdoor air from hour to hour and from day to day. When opportunity presents itself, a systematic investigation is to be carried out with respect to the effects of humidity, barometric pressure, and wind direction on the carbon dioxide content of outdoor air. The construction of the diaferometer and of the volumetric gas-analysis apparatus and the observations with them were carried out by V. Coropatchinsky.

*Combustible gases in animal respiratory exchange.* In the development of the modified Noyons diaferometer it was found that there was not always good agreement in the oxygen determinations by the diaferometer and by volumetric gas analysis when analyses were made of samples of air collected from respiration chambers in which animals had been breathing. This pointed to the possible presence of an un-

known gas in the respiratory exchange of animals, in addition to the known gases nitrogen, carbon dioxide, and oxygen. Preliminary observations have been made this year with respect to the presence of a combustible gas in the respiratory exchange of the cat. When a gas-analysis apparatus adapted for the determination of combustible gases was used, it was found that there is a definite trace of a combustible gas in this animal's respiratory exchange. These observations will be continued when opportunity presents. This finding illustrates one of the weaknesses of the diaferometer system, namely, that when another gas is present in an air sample in addition to those ordinarily present in atmospheric air, the oxygen determinations with the diaferometer are not reliable. On the other hand, it shows one of the advantages of the diaferometer in helping in the detection of unknown gases in respiratory exchange. The observations with the cat were made by George Lee.

*Metabolism in diabetes mellitus.* The respiratory exchange measurements on diabetic patients have been continued this year through the special grant from the Carnegie Institution mentioned last year, and with the cooperation of Research Associate Dr. Elliott P. Joslin, Medical Director of the George F. Baker Clinic of the New England Deaconess Hospital. The tests were made on 207 days and included 146 patients. The various phases of the investigation have included measurements

of the basal metabolism of each patient on one or more days and, on 116 days, observations regarding the effect on the respiratory quotient of administration of 50 grams of dextrose. Comparisons were made between the effects of the oral and the intravenous routes for administration of this sugar, and in a few cases insulin was given along with the sugar. With 14 patients comparisons were also made of the effects of ingestion of 50 grams of dextrose and of levulose. A study was made of the changes in the respiratory quotient after administration of dextrose with patients in diabetic coma, during severe acidosis, and during recovery from acidosis, with patients showing resistance to insulin, and with a few during insulin reaction. Charts showing the combustion of carbohydrates in patients of different types were prepared and exhibited at the annual meeting of the Massachusetts Medical Society in Boston on May 25 to 27, 1942, and at the meeting of the American Medical Association in Atlantic City, New Jersey, on June 8 to 12, 1942. At the latter meeting a special certificate of merit was awarded to the exhibit on diabetes mellitus, in which these charts were included. The investigation has been pursued this year on a full-time basis with the active cooperation of Dr. Howard F. Root. The respiratory exchange measurements were made by B. James, M. J. Blakely, G. Lee, and Jeannette F. Rayner.

## PUBLICATIONS

- (1) *Heat production of the rabbit at 28° C. as affected by previous adaptation to temperatures between 10° and 31° C.* Robert C. Lee. Jour. Nutrition, vol. 23, pp. 83-90 (1942).

Twelve adult rabbits lived for stated periods at a given temperature between 10° and 31° C. They were then kept at 28° and

without food for 24 hours, and immediately thereafter their oxygen consumption was measured at 28° C. The heat production, calculated from the oxygen consumption as thus measured, was compared with the *basal* heat production of each rabbit predicted from its body weight. Five rabbits, after living for 7 weeks at 17° C., had a heat production aver-



aging 19.0 per cent above their average predicted basal level. Their minimum heat production (7 per cent below basal) was found when they had been living for 3 weeks at 31° after a gradual approach from lower temperatures to this temperature. Seven other rabbits that lived for 9 weeks at 10° and later for 8 weeks at 29° C. showed deviations from basal of +17.0 and -1.5 per cent, respectively. Adjustment to increase in temperature occurred in a shorter time than adjustment to decrease in temperature. The major adjustment to increase in temperature toward thermic neutrality occurred in 2 to 3 weeks, but further adjustment continued for at least 2 months. In studies concerning the effect of any superimposed condition on basal metabolism, rabbits should be kept at 28° to 29° C. for 3 weeks prior to measurements, and their metabolism should be measured at this same temperature.

- (2) *A modified Noyons thermic diaferometer for respiratory gas analysis.* Thorne M. Carpenter and Vladimir S. Coropatchinsky. *Indus. and Engin. Chem., Anal. Ed.*, vol. 14, pp. 159-163 (1942).

This modified diaferometer was designed primarily for analysis of respiratory chamber air. The apparatus has two parallel pathways for two continuous streams of air, which are driven through absorbents for both carbon dioxide and water vapor or through an absorbent for water vapor alone. After passing through the absorbents, portions of the two streams of air are aspirated by a constant-level hydrostatic pump through chambers containing platinum resistance wires. These wires form two arms of a Wheatstone bridge system. The differences in the cooling powers of the gases passing through the two sides of the system are measured by the deflections of a delicate galvanometer. The apparatus has been standardized by comparisons of analyses of diluted respiratory air and analyses of atmospheric air, and constants have been established for the equivalent percentages of carbon dioxide content and oxygen deficit in samples of respiratory chamber air per millimeter deflection of the galvanometer. The total time required for analysis

of an air sample for both carbon dioxide content and oxygen deficit is about 17 minutes; the total volume of sample required for the complete analysis is 1 liter. Forty-six consecutive alcohol control tests on 5 days gave an average respiratory quotient of 0.662, with a standard deviation of  $\pm 0.0084$ . The standard deviation of the quotients from the theoretical alcohol quotient of 0.667 was  $\pm 0.0097$ .

- (3) *The respiratory quotient of protein of the Dalmatian dog.* Thorne M. Carpenter and Harry C. Trimble. *Jour. Nutrition*, vol. 23, pp. 345-349 (1942).

The respiratory exchange of an adult, female Dalmatian dog was measured in two series of experiments 11 months apart, either after several days of fasting or at varying lengths of time after ingestion of different amounts of casein or raw beef. The urine was collected by catheterization. Most of the nonprotein respiratory quotients were below 0.71. This finding could not be ascribed to errors in measurement, to formation of sugar from protein, or to excretion of uric acid, which is greater in this dog than in dogs of other breeds. As the urine did not show any signs of acidosis by a qualitative test and as the percentage of ammonia in relation to the total urinary nitrogen was not high enough in any case to indicate the presence of acidosis, it was assumed that the combustion of fat was normal. The respiratory quotients of protein, calculated on the assumption that the fat metabolism was normal, were all well below 0.81. The hypothesis is advanced that the respiratory quotient of protein of the Dalmatian dog, although varying with the condition of the animal with respect to fasting and ingestion of food, is lower in general than the usually accepted respiratory quotient of protein, 0.81.

- (4) *Carbohydrate combustion in human subjects after oral and after intravenous administration of dextrose.* Howard F. Root and Thorne M. Carpenter. *Arch. Internal Med.*, vol. 69, pp. 997-1004 (1942).

With four normal men, post-absorptive and sitting, the respiratory exchange was meas-

ured in three consecutive 10-minute periods. The men were then given 50 grams of dextrose by mouth or intravenously, and the measurements were continued for nine consecutive 15-minute periods. Samples of blood and urine were collected at intervals during the tests. The blood sugar was higher  $\frac{1}{2}$  hour after and lower 1 hour after intravenous injection of the dextrose than it was at the same times after oral administration, but

there was no difference in the values after  $2\frac{1}{2}$  hours. Sugar appeared in the urine only after intravenous injection. The increases in respiratory quotient, oxygen consumption, and carbohydrate combustion for  $2\frac{1}{2}$  hours after administration of the sugar were practically the same whether the sugar was given by mouth or by vein. There was a tendency for the increases to be insignificantly greater after oral administration.

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## SPECIAL PROJECTS: BIOLOGICAL SCIENCES

W. E. CASTLE, University of California, Berkeley, California. *Experimental studies of heredity in small mammals*. (For previous reports see Year Books Nos. 3 to 38 and 40.)

The investigations of the past year have been restricted to a further study of the linkage relations of genes of the rat (*Rattus norvegicus*). Several new mutant genes have been received from various laboratories where the mutations have been discovered among closely bred stocks used in nutritional, pathological, or psychological studies. It is generally known that Dr. Helen Dean King and Dr. Castle have been studying linkage in the rat for some years and have accumulated a nearly complete assemblage of the known mutant genes of the rat. This knowledge has inclined rat investigators not interested primarily in genetics to call Dr. Castle's and Dr. King's attention to promising genetic material which comes to their notice but which they are not in a position themselves to utilize. This kindly cooperation and the donation of genetic stocks are greatly appreciated.

One of the most interesting of the new mutants was discovered and described in the *Journal of Heredity* in 1941 by Dr. R. O. Greep, of the Squibb Laboratories at New Brunswick, New Jersey. It is called *incisorless*, for the two pairs of incisors, which characterize the entire family of rodents and are of such functional importance to them in obtaining food and as weapons of offense and defense, are entirely wanting in this mutant race. They are a kind of gnawing animal which no longer can gnaw. They are able to eat only soft or pulverized food. In competition with normal rats they would quickly perish in a state of nature. The mutation is a recessive in heredity and so true-breeding

from the start. From a single albino male which carried the mutant gene as a recessive but was entirely normal himself, having incisors as ordinary albino rats do, it has been possible to obtain numerous incisorless young among his second-generation descendants. It has also been possible to ascertain very promptly in what chromosome the gene is borne. The latter shows very close linkage with the gene *curly*, which lies at one extremity of the second chromosome. The crossover percentage with curly is apparently less than 1 per cent. There is another mutant gene also closely linked with curly, namely *anemia*, with about 2 per cent of crossing over with curly. Crosses are now being made to ascertain the order of the three genes, which must be either *Cu in an* or *in Cu an*. This same second chromosome carries also the gene for brown pigmentation, which lies toward the opposite end of the chromosome. Thus we now have 4 genes in the second linkage group, and 5 in the first (albino) linkage group, both being presumably in long chromosomes, 40 or more linkage units long.

Loss mutations such as incisorless are of much interest in their possible relation to evolution. In the rat loss of incisors would be fatal in a state of nature, but in other mammals it is conceivable that such a loss would be advantageous. Getting rid of a useless organ is no less profitable in evolution than acquiring a new and useful one. Paleontologists tell us that the early proboscids had a pair of incisors both above and below, like those of rodents but more tusklike and project-

ing straight forward. They were probably used in digging for roots or tubers. Later the tusks of the lower jaw disappeared completely and only the tusks of the upper jaw remained, as in the extinct mammoths and the living elephants. It seems probable that the tusks of the lower jaw were lost by a single mutation like that of the incisorless rat, it being advantageous that the size and functional importance of the remaining pair of tusks be increased, and the other pair, now a mere encumbrance, be lost.

Another loss mutation which proved advantageous probably occurred in the ancestral history of man, namely, loss of hair over most of the body. Other anthropoids have a complete hairy coat. Doubtless our ancestors also had such a coat. A hairless mutation in a tropical environment would probably be no handicap to man, but positively advantageous in relation to body parasites and protection from the heat, and man had sufficient ingenuity to devise clothing and seek out caves for protection from cold. Hairless mutations are of frequent occurrence in our laboratory animals. They have been obtained and their inheritance has been studied in rats, mice, and rabbits. In each case the loss mutation is a simple recessive in its inheritance. In man the supposed earlier

hairiness has been completely lost. There are no hairy humans except by an occasional possible reverse mutation, which is advantageous only for sideshow exploitation.

We now have 19 rat genes to work with. Eleven of these are borne in three chromosomes, constituting linkage groups I-III. Group I includes albinism, red-eyed yellow, pink-eyed yellow, waltzing, and Grüneberg's lethal. Group II includes curly, incisorless, anemia, and brown. Group III includes hairless and wobbly. Unassigned as yet to linkage groups are agouti, blue, curly<sub>2</sub>, jaundiced, kinky, hydrocephalus, cataract, and epilepsy. The last three are recent acquisitions as yet imperfectly studied, and whether they will prove available for linkage studies remains to be demonstrated.

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PAUL S. CONGER, United States National Museum, Washington, District of Columbia. *Investigations and preparation for publication of results of studies on Diatomaceae*. (For previous reports see Year Books Nos. 18 to 40.)

The work on diatoms during the past year centered largely on the continuation of several projects previously in progress, involving considerable investigation concerning the ecological and oceanographic importance of diatoms. This included a large amount of bibliographic work and organization of information with a view to making it more readily available.

The advent of the war necessitated a considerable diversion to preparation of the rarer and type parts of the collection, and of certain irreplaceable materials for quick removal in case of imminent need.

The needs of the war resulted in a number of unexpected and important developments involving diatomaceous materials or the methods of diatom research,

and requests for information from both the Army and the Navy were answered, as well as materials examined. A number of these matters are strictly applicable to the present emergency, but in one or two instances there is promise of large-scale permanent benefits.

General requests for information and inspection of materials during the year seemed correspondingly increased, diatomaceous materials finding a number of new and special uses. Particularly noteworthy were requests for information on culture of diatoms to be used in physiological and other investigations. Of special interest were identifications made for Dr. Harold J. Humm, of the Duke University Marine Biological Laboratory, in connection with his pioneering studies of the biological and chemical transformations on the beaches at Beaufort, North Carolina. Beaches constitute one of the most biochemically active and significant of all ecological environments, and the diatoms are one important factor in the transformations that take place.

Identifications were made for Dr. John Watson, of the Physics Department of the University of Toronto, in connection with investigations of the electron microscope, now published. New records of soil diatoms for the United States were included in identifications made for Dr. Arlo Smith, of the Texas Technological College. Work was continued on examination of diatoms of the Second Byrd Antarctic Expedition.

The course on diatoms, covering their biological, oceanographic, and economic importance, conducted for a number of years at the Chesapeake Biological Laboratory was temporarily discontinued in the summer of 1942 owing to war conditions.

In the course of investigation of the diatomaceous sediments of a 10-acre lake near Solomons Island, Maryland, a new and simple method was developed, and considerable work was done on what appears to be a very interesting and practically unstudied field, that of the ebullition of gases of decomposition from lake waters. This process is important in the decomposition of lake-bottom sediments, which results in the concentration of their diatomaceous constituents through the removal of the other materials, and it is also important in the rapid transformation and release of subsequently usable substances. The simple device developed for collection of such gases consisted of an inverted graduated tube sealed at its upper end, filled with water, and placed with its lower end passed through a supporting float and connected with a collecting funnel. As released gas bubbles arose they replaced water in the upper end of the tube, giving a daily reading of the amount of gas formed in a given area. By means of a number of these collectors anchored about the lake, the average production of a highly inflammable gas, apparently mostly methane, was found to be 90 cubic feet per acre per day in August, or 900 cubic feet over the whole lake per day. A report of the various aspects of this study is in preparation. The writer had previously experienced heavy gas production from other dried diatom sediments through destructive distillation. Examinations of the muds at different depths showed decided changes accompanying this process.

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TH. DOBZHANSKY, Columbia University, New York, N. Y. *Studies on the genetic structure of natural populations.* (For previous reports see Year Books Nos. 37 to 40.)

The course of biological evolution can be likened to a manufacturing process which involves three stages. The first stage is the production of raw materials, that is, of heritable variants. The heritable variants (gene changes and chromosomal aberrations) accumulate to a greater or lesser extent in natural populations of any living species. The presence of these variants, however, does not in itself guarantee that evolutionary changes will take place, just as the mere availability of raw materials in a factory does not guarantee the end product of the manufacturing process. The second stage entails a series of processes which combine the variants into organized systems, which are the hereditary endowments of new races and species. By analogy, the raw materials are thus molded into factory products. This is the part of the evolutionary process least understood. Finally, the third stage consists in the development of isolating mechanisms and the fixation of the nascent species. This stage can be compared to the packaging of the manufactured articles.

The origin of heritable variants is the most fundamental problem of the biologist in his attempt to understand the mechanics of evolution. This problem is being studied within the Department of Genetics of the Carnegie Institution of Washington by the group of investigators headed by Drs. M. Demerec and B. P. Kaufmann. The program of research which deals with the genetic structure of natural populations is the logical continuation of these studies. Inasmuch as it is established that new heritable variants arise from time to time in natural populations, their subsequent fate must be ascertained. This problem is, in turn, twofold: (1) the qualitative and

the quantitative composition of the accumulated store of heritable variants must be described, and (2) their reactions to the various agents which impinge upon them must be clarified. The first is the static and the second the dynamic aspect of population genetics. For several years past, investigations which bear upon both aspects have been carried on simultaneously, the fly *Drosophila pseudoobscura* serving as the test material. At present the work on the statics of natural populations is approaching completion. By "completion" it is not meant that the topic has been exhausted; the writer is conscious of the many deficiencies in the available information. The data as they now stand are, however, adequate for a general outline of the situation, and from now on it appears more profitable to concentrate on the dynamic aspect.

*Genetic variability accumulated in natural populations.* *Drosophila pseudoobscura* collected anywhere in its species area from British Columbia to Guatemala is singularly uniform in its structural characters. The observed variation is chiefly in the size of individuals, and most of this variation is nonhereditary. Only very seldom are individuals which display obvious hereditary variants found. For example, among the thousands of wild flies which have been observed at Idyllwild, Mount San Jacinto, California, during the summer of 1942, the only noteworthy variants were several specimens with a brighter than normal eye color.

This impression of uniformity is completely reversed if, with the aid of special genetic techniques, individuals homozygous for different wild chromosomes are obtained. A majority of wild specimens

carry various mutant genes in heterozygous condition. Some classes of mutant genes are amenable to exact quantitative estimation of their frequencies. Thus, it has been determined that in the wild flies which inhabit Mount San Jacinto,  $21.3 \pm 1.8$  per cent of the second,  $13.9 \pm 1.6$  per cent of the third, and  $25.5 \pm 2.2$  per cent of the fourth chromosomes contain recessive mutant genes which are lethal or semilethal to homozygotes. Since every fly carries each of the above chromosomes in duplicate, it can be computed that only about 25.5 per cent of the wild individuals are free of lethals and semilethals; 39.4 per cent have one, 25.0 per cent two, 8.3 per cent three, 1.5 per cent four, 0.14 per cent five, and 0.01 per cent six lethals or semilethals concealed in their germ plasms (these figures replace the preliminary estimates given in Year Book No. 40).

Furthermore, the chromosomes of many wild individuals carry recessive genes which, when homozygous, reduce the viability of their carriers to an extent which is perceptible but not sufficiently deleterious to be classed as semilethal. Quantitative estimation of the frequencies of such genes presents serious technical difficulties because the magnitude of their effects varies from semilethality to a barely detectable constitutional weakness. The best estimates available are that  $21.1 \pm 2.3$  per cent of the second, about 30 per cent of the third, and about 41 per cent of the fourth chromosomes contain genetic modifiers which are to some extent deleterious to viability. Making the necessary computations, we find that only 10.6 per cent of the flies in the natural populations are likely to be free from chromosomes which carry deleterious modifiers, and that 29.5 per cent will carry one, 33.3 per cent two, 19.6 per cent three, 6.2 per cent four, 1.0 per cent five, and 0.06 per cent six such chromosomes. It is apparent therefore that

perhaps no more than 2 per cent of the flies can be expected to be entirely free of lethals, semilethals, and deleterious modifiers of lesser degrees. Moreover, genes, most if not all of which are recessive, which modify the development rate of their carriers are even more widespread in natural populations than the viability modifiers just mentioned. A majority of these genes act, when homozygous, to slow down development, but some of them, on the contrary, accelerate it. In wild populations about 54 per cent of the second and 35 per cent of the fourth chromosomes contain detectable modifiers of the development rate; no estimate for the third chromosomes is available. About 13 per cent of the second and 8 per cent of the fourth chromosomes contain recessive factors which produce sterility of one or both sexes in the homozygotes. Finally, between 1 and 5 per cent of the second, third, and fourth chromosomes contain recessive genes which produce various effects on the visible morphology of the fly (these figures replace the preliminary ones in Year Book No. 40).

*A theory of hybrid vigor.* It is well known that inbreeding and consanguinity frequently result in deterioration of the stock, and that outbreeding is followed by so-called hybrid vigor or heterosis. These phenomena are clearly of importance in agriculture, as witnessed, for example, by the increased corn yield which is obtained by hybrid-corn plantings. Their sociological implications are probably also important. For more than two decades the degeneration which follows inbreeding and the increase in vigor which follows crossing have been ascribed, respectively, to homozygosis of concealed recessives and to masking of the latter by beneficial dominants. The results of analysis of wild populations of *Drosophila pseudoobscura* support this theory and permit further insight into the nature of heterosis. The



great majority of the recessives found in the chromosomes of the fly are deleterious when homozygous. Moreover, very few of the flies in natural populations are "normal" in the sense that they carry no concealed recessives capable of producing some kind of deleterious effect. The apparent uniformity of the individuals found in nature is basically a function of a great variety of chromosomes with *different* recessive mutants. Recessives may become homozygous and thus manifest themselves, chiefly through consanguinity. But the frequency of consanguineous matings depends on the effective size of the population and the variety of chromosomes it contains. The phenomena of heterosis depend therefore on the population structure of the species. The process of mutation constantly produces new genetic variants presumably in all species, and a majority of these variants are deleterious. The dominant and semidominant mutants are eliminated with relative promptness, hence the dominant alleles are in general more beneficial than the recessive ones. The recessive mutant alleles accumulate in the populations until their frequencies become sufficiently high so that homozygotes are produced at a rate which counterbalances the mutation frequency. The point at which the mutation is counterbalanced by elimination, in other words the equilibrium point, is a function of the breeding structure of the species. In species which reproduce by self-fertilization, the genetic variants become homozygous and subject to elimination by natural selection very soon after their origin. In such species the accumulation of concealed deleterious recessives will be small, and little if any heterosis will be observed, since only genes with very mild deleterious effects can become established in any one strain. The same situation is expected to obtain in species characterized by very small effective

population size. In species with a greater effective population size, many chromosomes will contain deleterious recessives. Inbreeding in such species will be distinctly deleterious and outbreeding beneficial, but inbred strains which would equal in vigor the outbred strains could be produced by careful selection. *Drosophila pseudoobscura* probably falls in this category. Finally, in species with very large population sizes, most if not all chromosomes will accumulate deleterious recessives. In fact, since the effect of natural selection in such species is limited almost entirely to heterozygotes, a condition might arise in which most of the genes would be represented by a multitude of alleles, most or all of them deleterious in homozygous condition. The phenomena of heterosis would be most pronounced in such species, and no amount of selection would suffice to produce a fully vigorous inbred strain. Cultivated maize is probably an example of this last category of species. Because of a lack of appreciation of their importance, however, studies on population structure in maize and other cultivated species have been neglected by agriculturists, and no decision can be reached at present concerning this subject.

*Concealed variability as a source of potential evolutionary changes.* The multitude of recessives known to be carried in natural populations in a concealed condition may constitute the raw materials of possible evolutionary changes. But the fact that the great majority of mutants are deleterious to their carriers offers a real obstacle to the acceptance of this view. The difficulty is resolved, at least in theory, by supposing that a mutant which is deleterious in a certain environment and in combination with certain other genes may be neutral or even beneficial in other environments and in combination with other genes. Experiments are in progress to test

the validity of this supposition, which, unfortunately, rests on speculation rather than factual data. The preliminary results can now be outlined as follows.

Some second and fourth chromosomes from wild populations of *Drosophila pseudoobscura* contain recessive mutants which, when homozygous, produce deteriorations of viability, modifications of the development rate, and other changes (see above). Stocks of flies with such chromosomes have been preserved to serve for further experiments. Homozygotes for these chromosomes are raised at three different temperatures ( $16.5^{\circ}$ ,  $21^{\circ}$ ,  $25.5^{\circ}$  C.) and at different degrees of crowding. A technique is used whereby the homozygotes are made to develop in the same cultures with sibs known to have the standard viability, development rate, etc. The chromosomes so tested display a variety of behaviors. Some chromosomes show essentially the same degree of viability at all the temperatures and at all degrees of crowding tried; the viability of other chromosomes is best at the lowest temperature and deteriorates at the higher ones; still others do best at the intermediate temperature; but none which prefer the highest temperature have so far been detected. At the same time, some homozygotes show the best viability in sparsely populated cultures, others in crowded ones. The viability of a heritable variant is therefore not an unalterable characteristic, but a function of the environment. The modifiers of the development rate have, thus far, behaved more stably. In other experiments, the chromosomes to be tested (a majority of which came from populations inhabiting Mount San Jacinto, California) are, by means of a series of crosses, placed onto the genetic backgrounds of unrelated strains. Strains derived from different parts of the distribution area of the species, a fairly large collection of which is being kept in the

laboratory, are used for this purpose. The outcome of these experiments cannot be reported as yet, but some data already obtained suggest that the same genetic variant may behave differently on different genetic backgrounds.

It is known that certain rare chromosomes, isolated from natural populations, when tested in homozygous condition have produced not a lowering of viability but an increase (see Year Book No. 40). Several such chromosomes have been included in the sample which has been exposed to different temperatures and different degrees of crowding, but not one has maintained its superior-to-normal record in all the conditions studied. It may be regarded as certain that the species contains genetic variants which are superior to the average norm under certain special conditions; but the same variants are inferior to the norm in other, and presumably more prevalent, environments. The interest of these findings is obvious. Variants of the above kind may be regarded as a safety valve maintained by the species against the contingency of environmental change. It is also possible that the species contains at all times a variety of genotypes, some of which are optimal under some and others under other conditions of the environment to which the species is normally exposed in the course of the seasonal cycle and in different microclimatic and microecological niches. If this surmise is correct, the genetic composition of the species must be in a constant flux. Indeed, natural selection would strive so to change the species genotype as to bring it up to the highest attainable optimum. But if the environment should change very rapidly in relation to the speed of reproduction of the organism, the latter might find itself always close to but never quite at the optimum goal. Data indicating that such a state of flux actually obtains in natural

populations of *Drosophila pseudoobscura* are available (see Year Book No. 40 for a preliminary report; a systematic collection of such data continues).

**Chromosomal variants.** Aside from the inheritable variants of genic nature, variations in the arrangement of genes in the chromosomes are also found in natural populations of *Drosophila pseudoobscura*. This phenomenon has been studied for about six years; the results are described in a small monograph now in preparation. For unknown reasons, the gene arrangement is far more variable in the third than in the other chromosomes. The variants are inversions of chromosome sections. In the third chromosome, at least nineteen different gene arrangements are known. Their geographic distribution has been traced in so far as the material available would permit. Their phylogenetic relationships have been established. At first sight, the geographic distribution pattern of the different gene arrangements appears extremely complex and irregular. Professor Carl Epling, of the University of California at Los Angeles, who has kindly consented to examine the pertinent data, has come to the conclusion, however, that an explanation of these complex distribution patterns may be sought in the history of the species in connection with the geologic history of its environment, particularly that of the floras of the Tertiary period. The striking, and altogether unexpected, inference reached by Professor Epling is that at least the phylogenetically basic arrangements existed in geologically rather remote times, as far back as the Oligocene, or even earlier.

**An attempt to determine the order of magnitude of certain basic constants of population dynamics.** The evolutionary fate of a species is determined in part by its intrinsic properties, its breeding structure, and in part by the environment in

which it lives. Among the intrinsic properties, the following seem most important: (a) A species with high mutation rates will, in general, be more plastic than a species whose genes are more stable. The mutation rate of a gene is expressed by its mutability coefficient,  $\nu$ . (b) A large undivided species in which the genes diffuse freely throughout the distribution area is less likely to differentiate into subspecies than a species split up into local colonies exchanging individuals (migrants) at a low rate. The rate of exchange of individuals between a colony and the rest of the species is symbolized by the migration coefficient,  $m$ . (c) A species with an effectively large panmictic population is evolutionarily more rigid than one with locally limited population sizes; the genetically effective population size is expressed by the Wright's constant,  $N$ . (d) Deviations from randomness of mating, for example frequent brother-sister mating, may upset the genetic equilibrium expected in a panmictic population. The degree of departure from randomness of mating may be expressed by the inbreeding coefficient,  $F$ .

The lethals and semilethals present in natural populations constitute, for several reasons, favorable material for studies on population dynamics. Lethals found in natural populations may be alleles because (a) lethal mutations of the same gene may arise recurrently at different times and in different places, and because (b) the progeny of a single mutant may increase and spread. Independently arisen lethals and lethals of common origin may be distinguished. In a large undivided species there should be no difference in the incidence of alleles among lethals found within a small territory and among those collected in remote territories. In such a species every lethal is expected to attain its highest possible equilibrium frequency

in every part of the distribution area. Conversely, restriction of the effective population size and migration barriers will cause the frequency of alleles among lethals within a small territory to be higher than that among lethals found in remote territories. Indeed, allelic lethals found in remote territories are independently arisen ones, whereas within a small territory both independent lethals and lethals of common origin will be found.

The lethals and semilethals in the third chromosome of *Drosophila pseudoobscura* have been chosen for detailed examination. Samples of lethals were taken at several collecting "stations" on Mount San Jacinto and in the Death Valley region, California. A "station" is a territory of at most 100 yards in diameter. The stations on Mount San Jacinto are grouped in three "localities"; the distances between stations in a locality are from  $\frac{1}{8}$  mile to 2 miles. The distances between the localities are from 10 to 15 miles. Mount San Jacinto is more than 200 miles distant from the Death Valley region. The frequencies of allelism among lethals recovered from various population samples have been determined (see preliminary data in Year Books Nos. 38 and 39). The most important fact is that the frequency of alleles among lethals coming from different localities and regions is only  $0.413 \pm 0.081$  per cent, whereas among lethals within a station it is as high as  $2.13 \pm 0.32$  per cent. It is clear that *Drosophila pseudoobscura* is a species differentiated into local colonies which differ in genetic constitution.

A mathematical analysis of the above data has been made by Professor Sewall Wright, of the University of Chicago. The conclusions are, briefly, as follows: It is reasonable to assume that the allelic lethals found in different localities and regions are almost entirely of independent origin. The frequency of alleles among independent

lethals is a function of the number of loci (genes) in the chromosome capable of producing lethals by mutation. On the assumption that the mutation rates are uniform for all loci, and that the lethals produce either no effect or a uniform effect on viability in heterozygotes, the number of lethal-producing loci in the third chromosome of *Drosophila pseudoobscura* turns out to be 285 (this figure is to replace the former estimate, 250, given in Year Book No. 38). If the above assumptions are not granted, the number of the loci is greater than 285, which is, hence, the minimum estimate. A maximum estimate, arrived at by a different method, is approximately 1100, but for our purposes the minimum estimate is preferable.

Knowing the incidence of third chromosomes carrying lethals in natural populations and the number of mutable loci, it can be computed that the average frequency of a lethal in the populations of Mount San Jacinto is approximately  $5.23 \times 10^{-4}$ , or 0.0523 per cent. Similarly, knowing the rate of origin of new lethals by mutation (see Year Book No. 38) and the number of lethal-producing loci, we find that the average mutation rate per locus per generation is  $\nu = 1.077 \times 10^{-5}$ . Now, in a population of a very large effective size the equilibrium frequency of an autosomal recessive lethal must approach the square root of the mutation rate producing that lethal. The observed frequency of lethals is much smaller than would be expected in such a population. This discrepancy may be brought about by one or by a combination of several causes. Among these causes, deviation from randomness of mating ( $F$ ) and a possible deleterious effect of the lethals in heterozygotes (expressed by a selection coefficient,  $s$ ) may be important. There being no way to differentiate between the effects of  $F$  and  $s$  on the basis of the avail-

able data, only a joint estimate of the value  $F + s$  is possible. For the populations of Mount San Jacinto this is close to 0.018.

The observed difference between the frequencies of alleles among lethals found within a station on one hand and those found in remote localities and regions on the other is produced by a restriction of the effective population size (the Wright's constant,  $N$ ) and a limitation of interchange of individuals between populations inhabiting different territories ( $m$ ). Again, the data do not permit rigorous discrimination between these variables. In view of the now known relatively high mobility of *Drosophila pseudoobscura* flies (see Year Book No. 40), however, it may be assumed that there is a fairly free interchange of germ plasms between populations inhabiting different stations within a locality on Mount San Jacinto. The value  $m$  for stations within a locality is assumed to be about 0.5, which is large enough to give no appreciable isolation. If so, the Wright's constant for a station is in the neighborhood of 50. The mobility of the flies is, however, not high enough to permit an appreciable migration from locality to locality. Assuming  $m$  for localities to be less than 0.01, the value of  $N$  for the largest locality on Mount San Jacinto (about 6 million square meters) is probably between 20,000 and 30,000.

The results reported in the foregoing paragraphs show how important it is to secure reliable information on the migra-

tion rates of *Drosophila pseudoobscura* in its natural habitats. A series of experiments designed to clarify this problem have been conducted in summers of 1941 and 1942 on Mount San Jacinto, California (see a preliminary report in Year Book No. 40). The experiments carried out in 1942 were more successful than those of 1941. The analysis of the resulting data will, however, require some time; it is hoped that the conclusions will be ready for presentation in the next annual report.

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CHARLES ELTON, Bureau of Animal Population, Oxford University, Oxford, England.  
*Research on natural fluctuations in North American animal populations.* (For previous reports see Year Books Nos. 37 to 40.)

The grant of the Carnegie Corporation of New York, through the Carnegie Institution of Washington, has again ensured the continuity of research into fluctuations

in North American animals, although war-time research is now the main occupation of the Bureau of Animal Population. Mrs. Mary Nicholson has helped Charles Elton

to finish a paper on the lynx cycle in Canada and has done the mapping for the two annual Canadian Wild Life Enquiries. The lynx paper, together with an earlier one on the muskrat, are the end products of part of a series of researches, begun in 1925, which have involved not only the accumulation of annual reports through the Hudson's Bay Company, but an examination of fur returns back to the eighteenth century. Both species show a well marked ten-year cycle covering a huge area. Peak years are not always synchronous: in the lynx, abundance is reached and passed first in the northwest, some two or three years before other parts of Canada.

Charles Elton's book *Voles, mice and lemmings: problems in population dynamics* (see bibliography) includes a great body of new data on fluctuations in North American animals: in particular, on the short cycle in colored and arctic fox in the eastern Arctic and Subarctic.

The "Canadian Arctic Wild Life Enquiry, 1940-41," by Dennis Chitty and Mary Nicholson, is in press. The year was remarkable for an almost universal improvement in arctic fox populations. "The Snowshoe Rabbit Enquiry, 1939-40" was published early in 1942, and the reports for 1940-41 have been mapped, but not yet published. A continent-wide increase in snowshoe rabbits was still continuing, and the regional occurrence of "crashes" is to be expected in the next few years.

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ARTHUR T. HERTIG and JOHN ROCK, Boston Lying-in Hospital, Boston, and Free Hospital for Women, Brookline, Massachusetts. *Research in embryology, embryological pathology, and reproductive physiology*. (For previous reports see Year Books Nos. 36 to 40.)

These studies on various early aspects of human reproduction have been continued with the financial support of the Carnegie Institution of Washington and in cooperation with its Department of Embryology. In addition, as in the past four years, Dr. Rock has received aid from the William F. Milton Fund of Harvard University.

Since the last report, the authors have succeeded in obtaining four more stages of early human development, three of them normal and the fourth pathological. Two of the normal fertilized ova are younger than any thus far obtained, and shed light on the critical period immediately following implantation of the human blastocyst.

These two stages are  $7\frac{1}{2}$  and  $9\frac{1}{2}$  days of age respectively. The third normal specimen is approximately 11 days of age and is intermediate in development between the two normal ova of 11 and 12 days, whose description has been published since the report in Year Book No. 40 (see bibliography).

In this study thus far, twelve early human ova have been recovered from uteri removed surgically prior to the first missed menstrual period. Seven of these specimens are normal and five pathological. Sixty-one hysterectomy cases have constituted the clinical material which has yielded these specimens, an incidence of

pregnancy in this group of approximately 20 per cent. This fact as well as other clinically important features, such as the probable time of nidation and the location of embedment, were presented at the annual meeting of the American Gynecological Society, June 1942. From these studies it is concluded: (1) that ovulation occurs approximately 14 days prior to the next expected menstrual period and (2) that nidation takes place at a variable stage of development of the blastocyst, on an endometrium which may vary in phase from the 19th to the 22d day. Furthermore, it was found that the seven normal conceptuses were implanted on the posterior wall of the uterus (without correlation as to the proximity of the corresponding active corpus luteum), whereas the abnormal ova were all on the anterior wall. Whether further specimens will make this distribution more apparent than real is problematical, but at least it is an interesting observation.

Much of this material was presented to the American Association of Experimental Pathologists in April 1942. The controlled experimental features of the study were stressed and the high proportion of pathological ova (42 per cent) was pointed out. This study indicates that the incidence of pathological ova is higher than the accepted incidence of spontaneous abortion of clinically diagnosed pregnancies (about 10 per cent) and brings the results more in line with the high incidence of pathological pregnancies in the lower animals (30-45 per cent).

The corpora lutea of these early pregnancies are being studied morphologically and a paper is being prepared for publication. It has been found that the normal fatty degenerative changes in the corpus luteum of menstruation are prevented from appearing at the usual time (23 days). This phenomenon is undoubtedly

correlated with the implantation of the ovum and its effect, either direct or indirect, on the corpus luteum.

A description of the new 11-day ovum was presented before the American Association of Anatomists in April 1942. At that time the point was stressed that the endometrium can be in a variable stage of development at the time of nidation, since we possess two 11-day ova of approximately equal development whose endometria are 2 to 3 days apart in their respective stages of secretory development. This biological variation has been confirmed and amplified in the subsequent finding of the 7½- and 9½-day ova, the endometrium of the latter being significantly older than that of either of the 11-day specimens. Hence, a given blastocyst can implant on secretory endometrium which may vary from the 19th to 22d day in its secretory development, as mentioned above.

Under the direction of Dr. Rock, the work on human ovarian ova has continued, with the chief objective of eliciting in vitro fertilization. Modifications of procedure during the past year have consisted in: (1) en masse culture of six to twelve eggs instead of manipulation of individual ova; (2) insemination in Locke solution after repeated washing of the ova; (3) varying the time intervals of pre-insemination and of post-insemination culture; (4) repeated changing of the culture medium after insemination in order to avoid infection.

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ELLIOTT P. JOSLIN, New England Deaconess Hospital, Boston, Massachusetts. *Studies of carbohydrate metabolism in diabetes at the New England Deaconess Hospital.* (For previous report see Year Book No. 40.)

During the past year, observations on diabetic patients have been continued at the George F. Baker Clinic of the New England Deaconess Hospital, utilizing the apparatus for determination of the metabolic rate and respiratory quotient provided by the Nutrition Laboratory of the Carnegie Institution of Washington.

Patients in acute acidosis and particularly during recovery from acidosis have been specially studied. In addition, problems connected with the efficiency of insulin action in relation to carbohydrate utilization have been investigated owing to the presence in the hospital of a number of patients illustrating various aspects of this problem. Summaries of the metabolic data in diabetic patients were made up in chart form and incorporated in an exhibit on diabetes mellitus at the annual

meeting of the Massachusetts Medical Society in Boston in May 1942. This same group of charts was used in a somewhat larger exhibit on diabetes mellitus which was presented at the meeting of the American Medical Association in Atlantic City, June 8 to 12. This exhibit and the lectures connected with it received a special certificate of merit from the judges of the scientific exhibit. The exhibit has been requested by the Medical Society of the State of Washington to form part of their scientific exhibit at their annual meeting in August at Spokane, Washington.

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CHARLES W. METZ and MARTHA LEE BOZEMAN, University of Pennsylvania, Philadelphia, Pennsylvania. *Chromosome studies on Sciara.* (For previous report see Year Book No. 40.)

*Evolutionary chromosome changes in Sciara.* The remarkable opportunities provided by the giant salivary-gland chromosomes of Diptera for studies on chromosome evolution have led to numerous investigations in recent years, notably on the genus *Drosophila*. Although far from complete, the studies of the various investigators on *Drosophila* have put the study of chromosome evolution in that genus on a new basis, much more accurate than was possible before, and have provided a large body of detailed information concerning

the changes occurring within the chromosomes during the course of evolution. In order to evaluate the broader significance of the findings in *Drosophila* it is necessary to determine whether or not they apply also to other groups of organisms. For this reason we have been making an intensive study of conditions in the genus *Sciara*, a group of fungus flies far removed taxonomically from *Drosophila*. These flies are especially favorable for the purpose, as was pointed out in earlier publications. In certain respects conditions in



*Sciara* apparently do not conform to the pattern established in *Drosophila*, and especial attention is being given to the points of difference. The major emphasis, in both genera, has been laid on morphological or quantitative chromosome changes. These involve rearrangement of parts (mainly inversion of pieces of various sizes within individual chromosomes) and loss or addition of parts. Rearrangements appear to be characteristic of *Drosophila*; they are found commonly within individual species and also are revealed by study of species hybrids. In *Sciara*, rearrangements apparently occur rarely in some species and more commonly in others. The reason for this difference is not yet evident. Rearrangements are to be expected in maximum numbers in species hybrids; yet careful comparative study of the organization of homologous chromosomes in hybrids between *Sciara ocellaris* and *S. reynoldsi* has revealed evidence of only two rearrangements (inversions), involving only one chromosome (unpublished observations of Dr. Pauline Rohm). In certain other species of *Sciara*, however, numerous rearrangements are found simply by examination of wild populations within the individual species, as was noted in last year's report.

Rearrangement of parts of chromosomes, unaccompanied by other changes, presumably can play only a very limited role in evolution. Additions of chromosome material, however, may provide the necessary basis for "progressive" evolutionary change in the germ plasm. As has been pointed out by Bridges, the "repeats" found in the salivary-gland chromosomes of *Drosophila* come in this latter category. They are relatively short regions which are present in duplicate within a chromosome. Presumably they have arisen by insertion within a chromosome of a small part of a sister or homologous chromosome. Such

"repeats" are found in small numbers in both *Drosophila* and *Sciara*. Especial interest attaches to the study of "repeats" in species hybrids, for such study gives an indication of how long chromosome material which is in duplicate, and therefore presumably not subject to the effects of natural selection in the same manner as other parts, can persist without modification. In *Sciara* a "triple repeat" is present in the X chromosome of each of the species mentioned above (*ocellaris* and *reynoldsi*). Although not yet complete in finer details, our study of this condition, including study of the hybrids between the two species, continues to indicate that the repeats are probably identical in the two species and hence that the condition has persisted without serious modification of the genetic material through the period of evolution of these species from a common ancestor.

In addition to rearrangements and "repeats," there are minute modifications which, in a descriptive sense at any rate, come in other categories. They appear to be rare in *Drosophila* and relatively common in *Sciara*. Some of them appear to involve the loss of single "bands" or disks, as seen in the giant chromosomes; they are designated "deficiencies." Others appear to represent a doubling of single disks or very short chromosome regions. They are referred to as "duplications" and presumably have much the same significance as "repeats," but their precise nature is not yet understood. For the latter reason, as well as because their mode of origin is unknown, these minute modifications are receiving especial study, particularly in the species hybrids mentioned above. Although this work has been extended during the past year, the results are not yet sufficiently clear-cut to warrant detailed discussion.

*Artificially induced chromosome changes.*

As was noted in earlier reports, the nature of the chromosome modifications in *Sciara*, and the relative frequencies of the different types as compared with those in *Drosophila*, make it important to get an understanding of the chromosome mechanisms responsible for the changes. The best approach to this problem seems to be through study of artificially induced chromosome modifications, using irradiation and other treatments. Such a study has been under way for some time and has received particular emphasis during the past year. The recent experiments are reviewed briefly below. In these experiments the treatment has been applied to the germ cells (mainly oöcytes) and the results have been observed by examining the salivary-gland chromosomes of the F<sub>1</sub> larvae. \*

Earlier work, reported last year, indicated that in the developing oöcytes of *Sciara ocellaris* the chromosomes are resistant to irradiation for a considerable period, judging by the absence of recoverable rearrangements following treatment. It also indicated that during the period in question the chromosomes undergo little, if any, movement, which suggested that perhaps absence of movement is here responsible for absence of rearrangements. In further investigation of the problem two lines of attack have been followed. One has involved an extension of the experiments and cytological observations to other periods of development in order to determine the exact limits of the "insensitive" period and to determine the morphological characteristics of the chromosomes at all stages in this period. The other has involved experiments designed to induce sensitivity to irradiation, or to induce rearrangements in the chromosomes, during the "insensitive" period. Such studies, if successful, ought to aid materially in revealing the nature of the chromosome mechanisms in question.

As a result of a large series of experiments, the limits of the "insensitive" period have now been defined with reasonable accuracy. In the present species the oöcyte chromosomes are "resistant" to irradiation with X rays, or gamma rays of radium, from about the beginning of the oöcyte growth period, during early larval life, until the second day after eclosion of the adult (approximately 15 days). By comparison with earlier cytological observations (Berry, 1941; Metz and Bozeman, 1940) it is seen that this period of resistance coincides with a period of prolonged "prophase" during which the synapsed chromosome pairs remain in condensed long threads evenly spaced about the periphery of the nucleus. Reynolds (1941) demonstrated that during the second day of adult life of the female the unlaid eggs become sensitive to the effects of X rays, and that this sensitivity starts at about the time the oöcyte chromosomes begin to move onto the spindle.

Since one of the obvious changes associated with increased susceptibility to X rays is movement of the chromosomes, it was thought that rearrangements might be induced by combining artificially induced movement with irradiation. Experiments were carried out to test this possibility. Presumably movement alone does not produce aberrations, because spontaneous rearrangements are rare in *Sciara*; nevertheless the possibility was tested in some of the experiments.

At about 26 hours after eclosion, at 23° C., the first meiotic division begins, and it proceeds to first anaphase by about 29 hours. The two groups of chromosomes are then well separated and remain in this condition until the eggs are laid, about 24 hours later.

It was found that the chromosomes of the larval oöcyte nuclei could readily be displaced by centrifugation. A force of

about  $1700 \times$  gravity applied for 1 hour will move the chromosomes into a small space at the centrifugal end of the nucleus. In this condition individual chromosome threads cannot be distinguished and the chromatin appears to be a mass occupying about one-tenth of the volume of the nucleus. No rearrangements were found in 72 slides from centrifuged material.

On the assumption that induced movement combined with radiation might be effective in bringing modified chromosome regions or broken ends into proximity and hence provide opportunity for rearrangement to occur, larvae were centrifuged before and after irradiation. The cytological stage of every group of experimental animals was determined by examination of ovarian smears of sister flies made at a time as nearly as possible coincident with the time of treatment. In the first such experiment, using dosages of  $1700 \times$  gravity and 2 gram-hours exposure to radon, the fertility was very low and only 12 preparations were obtained. No rearrangements were found in these. In a second experiment an X-ray dosage of 1980 r units and a centrifugal force of about  $5000 \times$  gravity were used. From material irradiated after centrifuging, the counts were as follows: 26 unaffected, 2 probably unaffected, and 4 unfavorable for study; from material irradiated before centrifuging: 60 unaffected, 8 probably unaffected, and 11 unfavorable.

Though no rearrangements were detected after centrifuging and irradiating in close sequence, it seemed possible that the effect of the radiation was delayed and that rearrangements might occur if the chromosomes were brought into proximity at some hours after irradiation. To test this possibility, five experiments were carried out. A dosage of  $5000 \times$  gravity and of 3000 r units was used in each case. The results may be summarized as fol-

lows: (1) Centrifugation  $\frac{1}{2}$  hour before irradiation, 8 specimens, no rearrangements; (2) centrifugation  $\frac{1}{2}$  hour after irradiation, 28 unaffected, 1 rearrangement (small deletion); (3) centrifugation  $1\frac{1}{2}$  hours after irradiation, 22 unaffected; (4) centrifugation 4 hours after irradiation, 25 unaffected, 1 rearrangement (reversed repeat); (5) centrifugation 20 hours after irradiation, 30 unaffected.

The number of rearrangements found in this experiment is too small to permit the conclusion that they were induced by the combined treatment. They may have been induced by the irradiation alone or possibly have been spontaneous.

Chromosome movement was also induced by immersing larvae in paraffin oil, which causes partial asphyxiation and irregular clumping of oöcyte chromosomes, but no rearrangements were induced by this treatment (18 specimens). Larvae were asphyxiated and then irradiated in an attempt to induce rearrangements. An X-ray dosage of 5000 r killed all the asphyxiated larvae and 17 of the 22 unasphyxiated controls. The survivors were sterile. Two adults emerged after asphyxiation followed by irradiation with 2530 r units, and no rearrangements were found (51 specimens).

The work just described was all done on larvae in which the chromosomes were condensed and distributed about the periphery of the nucleus. The dosages used were approximately 2000 to 3000 r. A total of 435  $F_1$  larvae examined showed only 2 rearrangements. The same general cytological condition persists through the pupal stage and the first day of adult life. In considering later stages, especial interest attaches to the correlation between the mitotic activities of the chromosomes and susceptibility to X rays. Prepupae and pupae irradiated with a dosage of 4 gram-hours of radon showed 351 unaffected and

1 rearrangement. Earlier work of Metz and Boche (1939) indicated that during the first day of adult life females were resistant to irradiation, and this observation was supported by further work in which, using females irradiated at less than 30 hours after eclosion, there were no rearrangements in 56 specimens. Reynolds (1941) extended the period of irradiation into the second day of adult life. Rearrangements were induced at 28 hours after eclosion, when the chromosomes were "late prophase tetrads," and susceptibility was found to increase as meiosis progressed to metaphase. We have repeated this work, with controlled temperature of 22-23° C., using a dosage of about 1100 r. Control smears showed that metaphase of the first meiotic division is reached at about 26 hours. There is some variability in stage in any one ovary, and presumably more between individuals of the same age.

Irradiation of adults younger than 22 hours (prophase) produced no rearrangements (6 specimens). Irradiation of adults 22-24 hours old (beginning of prophase movement) produced aberrations in 4 specimens (14 per cent affected). Irradiation of adults 25-26 hours old (metaphase) produced aberrations in 9 specimens (19 per cent affected). Irradiation of adults 27-31 hours old (anaphase) produced aberrations in 18 specimens (25 per cent affected). Irradiation of adults 54-55 hours old (anaphase) produced aberrations in 10 specimens (50 per cent affected). These results indicate that the incidence of susceptibility coincides with the beginning of meiotic movement, and increases throughout the meiotic period. Further experiments are being carried out to determine more exactly the correlation of these phenomena.

A period of mitotic activity precedes the growth period of the oöcytes, and larvae were treated during these gonial divisions to determine whether chromosomes at this

period were also susceptible to irradiation. Age is measured from the day the adults were mated. Hatching occurs at about 7-8 days. A dosage of 1000 r was used. Irradiation of larvae 13 days old produced 2 rearrangements, with 1 unaffected; irradiation of larvae 14 days old produced 10 rearrangements, with 88 unaffected; irradiation of larvae 15 days old produced 3 rearrangements, with 32 unaffected. A higher dosage (2500 r) was used on older larvae, and no rearrangements were induced in larvae 20 days old (101 specimens); 2 aberrations were induced in larvae 21 days old (47 unaffected). The larvae used for combinations of irradiation and centrifugation were 25-29 days old, and 2 aberrations were induced (435 specimens). The highest percentage of rearrangements occurred in 13-day larvae, but the number of flies is too small to permit the conclusion that this stage is most susceptible. The period of sensitivity ends with the onset of differentiation, and almost no rearrangements can be induced after the chromosomes become condensed into prophase threads.

Although not demonstrative, evidence obtained in these recent experiments suggests that a correlation exists between the types of chromosome rearrangement secured and the stage of mitosis (or meiosis) at which the treatment is applied. Early in the study of the aberrations induced in young larvae, a chromosome configuration never before reported in *Sciara* was detected. This was a duplication of a segment of chromosome, usually added so as to form a "direct repeat" with no intervening material. Three duplications formed reversed repeats similar to that described by Kaufmann and Bate (1938) in *Drosophila*. In all these duplications intimate synapsis occurs among all three homologous segments. Larvae irradiated during the gonial mitoses probably have all

mitotic stages present. Among 16 aberrations from such material there were 7 repeats, 4 inversions, 2 translocations, and 3 deletions. In larvae irradiated at 21 days (arrested prophase), 1 inversion and 1 reversed repeat were found. In later larvae in the same cytological stage, 1 deletion was induced in a female, 1 reversed repeat in a female or male, and 1 direct repeat in a male. The only aberration found in offspring of irradiated pupae was a translocation, but this may have been induced in a male.

By the irradiation of adults 22-24 hours old, in which the oöcytes are in prophase of the first meiotic division, only direct repeats were induced. By irradiation of adults 25-26 hours old, in which the oöcytes are mainly in metaphase but also show some prophase and anaphase figures, 4 direct repeats, 1 inversion, 3 deletions, and 1 repeat of a section at some distance

were caused. By irradiation of adults 27-31 hours old, in which the oöcytes are mostly in anaphase, 6 direct repeats, 22 inversions, no deletions, 1 translocation, 3 transpositions of segments, and 3 duplications of segments at some distance were induced. By irradiation of adults 54-55 hours old, 7 repeats, 8 inversions, and 2 deletions were induced.

The lowest percentage of direct repeats is obtained from flies irradiated in the period from 27 to 31 hours (when the oöcytes are in early anaphase), and the highest percentage of repeats occurred in flies irradiated in the period from 22 to 24 hours (when the oöcytes are in prophase).

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T. H. MORGAN and JACK SCHULTZ, California Institute of Technology, Pasadena, California. *Investigations on the constitution of the germinal material in relation to heredity*. (For previous reports see Year Books Nos. 15 to 40.)

The report by Dr. Jack Schultz which follows is based on the work of the period ending January 1942. In last year's report there was discussion of several series of experiments designed for a study of the functional differentiation of the chromosomes. The convergent genetic, cytological, and cytochemical studies have been pursued.

The study of the function of heterochromatin by means of the analysis of the variegated types of *Drosophila* has been continued. The distribution of heterochromatin in the chromosomes has been studied, by the analysis of the modifiers of the grade of variegation. Since the grade of variegation depends, other things being equal, on the heterochromatin balance of the nucleus, it was reasoned that the de-

termination of the loci of a series of modifiers of variegation would permit the detection by genetic means of possible "interstitial" heterochromatin, in addition to the centromeric heterochromatin already studied. The experiments on the localization of these types have been continued, but are not yet ready for complete report. Accumulation of analyses of the many individual cases continues, and the statement of last year's report that the majority of the modifiers are themselves rearrangements affecting centromeric heterochromatin has received supporting evidence from new cases; in addition, some new instances have been observed of modifiers located in the more distal regions, presumably in the so-called "interstitial" heterochromatin.

The detailed analysis of the function of the heterochromatin of the second chromosome led, as was reported last year, to the discovery of a differentiation between the heterochromatin of *Drosophila melanogaster* and that of the closely related species *D. simulans*. It will be recalled that it was possible to show that striking abnormalities in the growth and differentiation of the organs of the hybrids were induced by a deficiency of the heterochromatin in the right limb of the second chromosome. Continued analysis has shown that the melanotic necrosis ("tumors") of the fat bodies (one of the characteristics in these crosses) may occur without the appearance of the duplicated organs, and that it is apparently specifically related to the rolled mutant. The previous work had shown that the hybrid males with a *simulans* X chromosome showed the "tumors" but not the duplicated organs. A new type of female hybrid, containing two *simulans* X chromosomes, from the progeny of mating attached-X *simulans* females to *melanogaster* males, displays, as the males did, only the "tumors," and no duplicated organs. The conclusion is therefore confirmed that the X-autosome relation, and not the sex of the hybrids per se, determines whether duplicated organs occur. Nevertheless, there is a relation between the melanotic "tumors" and the duplicated organs: the duplicated organs in these crosses have not been observed except in individuals containing "tumors" as well. The relation still remains to be worked out, since different strains of *simulans* differ in their behavior in this respect.

The question of the possible relation of these effects in the hybrid to the effects on variegation of the *melanogaster* deficiency Minute S10 has been studied. Experiments on the variation of the heterochromatin balance in relation to the effects of the deficiency have been carried out. The

Minute in question is a slight type, which, when heterozygous for the mutant rolled, permits the variable manifestation of the rolled effects in a form not quite so extreme as the other deficiencies for the rolled locus. It was found that the Minute S10 effects themselves show some variation with heterochromatin balance within the species *melanogaster*: the XO males show spread wings and their bristles appear coarser than those of the XY males, with some supporting but not conclusive evidence that the addition of Y chromosomes further intensifies the Minute effect. It is already known that in the variegational chromosome rearrangements between heterochromatic and euchromatic segments, addition of heterochromatin to the nucleus causes the heterochromatic genes brought near the euchromatin in the rearrangements to display the phenotype of the recessive mutants known at the loci in question. Thus the "light" locus is in heterochromatin, and in rearrangements where it is transferred to euchromatin, the phenotype of the heterozygote for light and the translocation is wild type in the XO male, light in the male with three Y chromosomes. Similarly in the present deficiency for the heterochromatin block, if the rolled locus were present, but undergoing a modification of function due to its position closer to euchromatin, it would be expected that addition of Y chromosomes to the genotype would increase the intensity of the rolled effect. Experiments to test this possibility have so far shown that this is not the case, and that the manifestation of rolled is the same in both XX and XXY individuals. There are, however, lethal effects, and a certain half-thorax type appearing in the deficiency-rolled heterozygotes, which are not yet explained. It is evident, however, that the simple postulate of an interaction in

the hybrid between a modified heterochromatin balance and a variegational translocation is not sufficient to account for the situation.

Last year the discovery was made that the heterochromatic regions divide more slowly in the endomitotic divisions of the nurse cells than do the euchromatic regions. Further evidence has been obtained from the study of the nurse-cell divisions in other species of *Drosophila* (*virilis*, *robusta*, *simulans*, *pseudoobscura*) that the picture is consistent within the genus. A preliminary study of *Calliphora viridescens*, however, shows a slighter difference between the rates of division of the euchromatin and the heterochromatin of the nurse cells. This finding is of interest in connection with the work of Geitler on the behavior of heterochromatin in the endomitotic divisions of the Hemiptera, in which he considered the number of heterochromatic masses in the nucleus as an index of the number of endomitotic cycles, and found a rough correlation with the nuclear volumes. This offers a striking contrast to the picture of unequal rates of division in the *Drosophilas*. The situation in *Calliphora* is apparently intermediate between that in the *Drosophilas* and that in the Hemiptera studied by Geitler. It seems not unlikely that in different species, and perhaps within the species among the different tissues, the variation of rates of endomitotic division for the different parts of the chromosomes (or the genes themselves) may be characteristic for each type of cell.

The cytochemical analysis of the chromosomes by the combined use of staining technique and enzymatic digestion has been continued. The present series of experiments had as their object a survey of the differential resistance to digestion by the enzyme ribonuclease of nuclei at dif-

ferent stages of mitosis, or of differing structural types. It will be recalled that the results of last year cast doubt on the reputed specificity of this enzyme for ribose-nucleic acid, unless it were assumed that the structural framework of the chromosomes of the salivary gland is a ribosenucleic acid. In the present study, covering *Narcissus* root tips, grasshopper and salamander testes, and sperm of *Chaetopterus*, *Chiton*, *Ciona*, *Cynthia*, *Lytechinus*, *Megathura*, and *Patiria*, as well as the eggs of some of these types, evidence of the same sort was obtained. Metaphase chromosomes, the bands of the salivary-gland chromosomes, and highly condensed sperm heads such as those of *Chiton* and *Drosophila* proved most highly resistant. The most sensitive structures were those of the "resting nuclei." In the cytoplasm of the eggs examined, it appeared that some of the protein (staining with the fast green stain) was digested away, showing that other substances in addition to the ribose-nucleic acids of cytoplasm are affected by the enzyme. From these results it follows that during those stages of the nuclear cycle when the concentration of protein is high, either ribosenucleic acid is present in the chromosomes, or (in agreement with data of Dr. Mazia) a protein fibrous structure in the nucleus is digested by the enzyme. The cytochemical data are at present consistent with either hypothesis, since the apparent correlation of ribose-nucleoproteins with the processes of protein synthesis calls for their presence in the resting nuclei, and not in the metaphase, where synthesis is presumably at a minimum.

There is a further agreement to be noted between these results and the recent application to mitosis, by Caspersson, of the Miescher-Kossel hypothesis of a change in the protein constituents of the nucleus.

According to this view, the complex proteins of the nucleus are broken down during the prophases, and the proteins remaining are nucleohistones or protamines.

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From the starting point of an experimental dietary which, like many present-day human food supplies, was adequate for the perpetuation of the population in passable health, but suboptimal, as shown by its nutritional improvement under controlled conditions, the chiefly significant enrichments appeared to be those of calcium and riboflavin content and of vitamin A value. The constructive character of the findings with these three chemical factors gave rise to a new research to determine how far the favorable effects of these increased nutritional intakes can be explained by increased concentrations of these nutrients in the essential substance of the body. By analytical methods, whether of the classic type with modern improvements, or physicochemical, or biochemical, we seek to ascertain just what degrees of normal flexibility actually exist in the traditionally alleged *fixité* of the body's internal chemistry. The experiments with diets of different calcium content were completed in 1941. The corresponding experiments with different levels of nutritional intake of riboflavin and of vitamin A have been and are being continued, but in each case the rate of progress has been slowed down by war conditions, research assistants having resigned to take up work on more directly military problems. The nutritional problems here under consideration, however, undoubtedly have such significance for the maintenance and upbuilding of human

health and efficiency that the fact of our being at war accentuates the importance of completing this research.

In the experiments of the past year, a doubling of the riboflavin content of the food, within the range which supports the "plateau of optimal performance," has appeared to induce a slightly higher concentration of riboflavin in the liver, which difference increases with physical maturity; and a probably insignificantly higher concentration in the muscles, whose riboflavin content seems to diminish with increasing age. The cases thus far studied are too few to permit a definite conclusion as to the significance of these small differences in the analytical findings.

Satisfactory completion of these riboflavin studies will require extension of the experiments to larger numbers of cases and through a wider range of age, with attention not only to the level of nutritional intake of riboflavin itself, but also to that of phosphate and protein. The latter point particularly needs investigation because it is now known that riboflavin functions importantly in the tissues in combination with phosphate and protein.

In the studies of the effects of enrichment of dietaries with vitamin A, the work of the past year indicates the importance of the higher intakes for the maintenance of full bodily reserves and optimal nutritional well-being with increasing age, even from earliest adulthood. Hence this part of the research also carries human implica-



tions to which the war gives accentuated significance.

Both the riboflavin and the vitamin A experiments will therefore be continued to the extent that the existing opportunity permits.

The generous and efficient service of those who have collaborated in the work

here reported, whether as research assistants or as volunteers, is gratefully acknowledged.

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## DIVISION OF HISTORICAL RESEARCH

*Cambridge, Massachusetts*

A. V. KIDDER, *Chairman*

Well before the entry of the United States into the war it had become evident that the general financial situation along with the rapidly expanding defense activities of the Institution would sooner or later necessitate curtailment or deferment of customary and normal research programs. The Division's 1941-1942 program was accordingly formulated with a view to gathering as great an amount of raw data as possible in order that members of the staff not in war service might be able profitably to pursue their studies, for a relatively extended period, with a minimum of expense for field work. The season therefore opened earlier than usual, and when hostilities broke out, several parties were already in Central America and others were on the point of departure. Inquiry as to further procedure brought instructions from the Institution headquarters that original plans should be followed; and, later, the United States legations in the countries concerned requested that undertakings having value in supplementing the Government's program of inter-American cultural relations be continued. All scheduled explorations and excavations could thus be carried to completion. When the Axis submarine campaign was extended to the Gulf of Mexico and the Caribbean, however, it was decided that irreplaceable specimens and notes should not be exposed to the risks of ocean transportation. Hence Messrs. R. E. and A. L. Smith, Strómsvik, Shook, Ruppert, and Richardson are remaining in Central America to work up their materials.

An unusually large number of excavations were undertaken. In Yucatan, Dr.

Morley cleared the elaborately decorated façade of a buried temple at Uxmal; Messrs. Brainerd and Andrews worked at Mayapan, Acanceh, and other ruins in the northern part of the peninsula, gathering ceramic and architectural data which will be of much value in interpreting the later prehistory of that region. In Guatemala, the investigation of the great archaeological site of Kaminaljuyu in the outskirts of Guatemala City was continued. Mr. Shook completely excavated a large mound, which proved to contain a superposition of four structures, and three tombs, one of them the richest in pottery and jades so far found at Kaminaljuyu. Mr. A. L. Smith worked on three of the several rectangular courts in which the ancient ceremonial ball game was played. These yielded a number of fine stone sculptures, mostly serpent and parrot heads with human faces in their open mouths. The Chairman devoted the season to preliminary study of the great amounts of pottery recovered by Messrs. Shook and Smith.

In Honduras, Mr. Strómsvik carried into its eighth year the program of excavation and preservation of the ruins of Copan, sponsored jointly by the Government of Honduras and Carnegie Institution. He completed the repair of Temple 11, now known, because of the long hieroglyphic texts adorning its walls, as the Temple of the Inscriptions. He also discovered south of the Acropolis an area containing numerous graves. As these held a great many mortuary vessels, representing several periods, his collections will throw much light on the local sequence of pottery types.

The excavations at San Andres, El Sal-

vador, directed by Mr. John Dimick were not pursued this year because of Mr. Dimick's entry into war service, but his assistant, Mr. S. H. Boggs, remained in Salvador to make a photographic record of the many large private collections of archaeological specimens in that country. Correlated with the Division's program was a survey of eastern Salvador by Mr. John M. Longyear, of the Peabody Museum of Harvard University, a project carried out under the auspices of the Institute of Andean Research with funds provided by the Coordinator of Inter-American Affairs. The Chairman served as director and visited Mr. Longyear several times in the field. The latter made a reconnaissance of the country east of the Lempa River, locating and mapping a large number of sites. He also excavated a small ruin at Los Llanitos, south of San Miguel, which proved to contain an interesting ball court, the southernmost yet recorded. Mr. Longyear's report will be issued by the Peabody Museum.

In Nicaragua, Messrs. F. B. Richardson and Karl Ruppert continued the investigation at El Cauce, near Managua, where in 1941 Mr. Richardson discovered human footprints in a deeply buried layer of consolidated volcanic mud (Year Book No. 40, pp. 300-302). The footprints were followed for several meters farther and a protective structure was erected over them. Mr. Ruppert devoted the season to study of archaeological remains in the recent deposits overlying the volcanic strata. Final judgment as to the antiquity of the footprints must await the working-up of Mr. Ruppert's materials, further research on the volcanology of the region, and paleontological studies bearing on the age of cer-

tain animal tracks found by Mr. Richardson.

No field work in ethnology or linguistics was undertaken, as Drs. Redfield and Tax and Messrs. Villa and Rosales were engaged in preparing reports on earlier investigations. Dr. Abraham M. Halpern joined the staff in 1941 to continue the study of Maya languages which was interrupted by the death of Dr. Andrade. Dr. Halpern, however, has been granted leave of absence for war service.

Researches in the history of science and in documentary history have gone forward, Drs. Sarton and Pogo working in Cambridge, Dr. Stock in Washington, and Mr. Scholes and Miss Adams in Albuquerque, where Mr. Scholes also conducted a course in methods of archive study at the University of New Mexico. Dr. Chamberlain is on leave of absence, acting as Senior Cultural Assistant in the United States Legation at Guatemala City.

During the year the Division lost, through resignation, the services of Dr. Oliver G. Ricketson, Jr., a valued member of the staff since 1922. Dr. Ricketson accompanied Dr. Morley on several journeys of exploration in the Peten; he was in charge of the initial excavations in the Northeast Colonnade and the Caracol at Chichen Itza; he investigated the ruins of Baking Pot, British Honduras; he inaugurated and for several years directed the extremely important excavations at Uaxactun in the heart of the Peten jungle. To Dr. Ricketson's ability as an organizer and leader of expeditions into difficult country, and to his skill as a field archaeologist, is due a very large share of our present knowledge of the Maya Old Empire.

## ARCHAEOLOGY

## HONDURAS

G. STRÓMSVIK

As in former years, the activities of the Copan expedition, a project sponsored jointly by the Government of Honduras and Carnegie Institution, comprised both repair of buildings and excavations with purely archaeological objectives. Mr. Strómsvik was again in charge, assisted by Mr. Douglas Elliott and Sr. Jesus Nuñez, the latter completing the Spanish catalogue of the large collection now housed in the Copan museum.

The work of preservation was concentrated on the Temple of the Inscriptions (Temple 11), which in its day was perhaps the most imposing of the many elaborately adorned buildings of the Acropolis, as it dominated both the Court of the Hieroglyphic Stairway and the West Court. In previous seasons much repair had been carried out on the temple proper, and the great range of steps mounting to it from the Court of the Hieroglyphic Stairway had been cleared of debris and its upper parts consolidated. Much remained to be done, however, on the other side, where the stairway rising from the West Court to the first platform and that from the platform to the temple were badly broken down. Also, the seven terraces flanking the stairways had been so badly warped and the masonry so skewed by the enormous weight above them that it was deemed advisable to take them down stone by stone and rebuild them. As has always been Mr. Strómsvik's practice in such work, the areas to be dismantled were carefully surveyed and photographed, and each stone numbered before removal. Study of the plans and sections made clear certain previously unknown features of construction, and there

came to light, during the removal of fallen material, a number of fine sculptures fallen from the western and southern façades of the temple. In addition to the resetting of the western stairways and terraces, the south side of the temple substructure, the east half of the south stairway, and the southwest corner of the temple were rebuilt.

In former years the East Court had been entirely cleared, save for a great pile of fallen masonry in the northeast corner. This pile not only detracted from the appearance of the court, but offered the only hope of recovering sculpture from Temple 20, the greater part of which had gradually been eaten away as the Copan River, before its diversion, cut into the Acropolis. The heaped debris was cleared away, the excavation bringing to light materials which proved that the entire west façade of the temple had fallen forward onto its frontal stairway. From the heap came several hundred pieces of carved stone, among them some of the finest yet found at Copan: geometric elements, grotesque animal and human forms, dozens of Ahau faces of various sizes, and many finely sculptured human heads, from half natural size to as much as 0.75 m. high. These showed such great individuality as to suggest that they were portrait studies. There were also recovered more fragments of the large bat figures found earlier at the edge of this heap. It is thought that the bats were roof ornaments, standing free atop the west façade. Most of the above-mentioned sculpture is now arranged in rows along the steps of Temple 20; certain outstanding pieces have been moved to the museum.

Another phase of preservation work was the solidification of the tunnel under the Temple of the Inscriptions, about 30 m.

of which were lined with lateral masonry walls and roofed with a corbeled vault, to guard against possible cave-ins and leave the tunnel open for inspection by students and visitors who may wish to see the many interesting superimposed constructions that went into the building of the Acropolis. Minor tasks were the repair of a large jaguar sculpture, on Platform 20, which now lacks only the head and the feet on the left side; and the setting upon a solid base of the gigantic head at the northeast corner of the Temple of the Inscriptions.

The more strictly archaeological work of the season was largely confined to digging in search of burials and stratified rubbish deposits in the vicinity of the Acropolis. During the rainy season of 1941 two burials had been washed out of the riverbank 200 m. south of the Acropolis. Following this lead, a trench was run west from the bank, revealing an extensive and long-used cemetery. In the excavation of no more than 150 cu. m. of earth 25 burials were found, from close to the surface to a depth of over 3 m. Three distinct strata were recognizable: the uppermost assignable to the late or Great Acropolis period; the middle to the first or Early Acropolis period; the lowest, in which hardly any cut stone was found, to the pre-Acropolis period. Although most of the burials contained no mortuary offerings, some were provided with pottery vessels and jade, shell, and clay ornaments. About 50 pieces of pottery, whole or repairable, were recovered. Most of the skeletons were so rotted that only the teeth could be preserved. A number of these were inlaid with jade. Burials of the three periods may be characterized as follows:

Late or Great Acropolis period: Bodies usually placed flexed in rectangular masonry cists of well squared stones. Inlaid teeth common. Great variety of pot-

tery types, shapes, and colors; polychrome abundant; Copan adaptation of Usulután ware rare. Yajoa ware appears. Great quantities of the small, crude votive vessels usually called *candeleros*. Tentative dates for this period: 9.10.0.0.0 to 10.0.0.0.0 in the Maya time count.

First or Early Acropolis period: Bodies laid flexed in open ground, occasionally in burial cists of cut stones. Inlaid teeth present. Polychrome and "Copan red" pottery appear; many basal-flanged bowls; Copan adaptation of Usulután style common, incised black ware common, carved slab-legged cylinders with lids, many *candeleros*. Tentative dates: 8.15.0.0.0 to 9.10.0.0.0.

Pre-Acropolis period: Three skeletons found, all extended; two in crude oval burial cists of uncut stones and river boulders, roofed with large unshaped slabs. Length of skeletons as they lay in the ground: 1.61, 1.62, and 1.63 m. No inlaid teeth. Pottery: red-on-buff, ring-base bowls with red rim, true Usulután plates with large bulbous legs, red-on-cream effigy jugs, carved slab-legged cylinders with lids, many *candeleros*. Tentative dates: ? to 8.15.0.0.0.

Metates without legs and with tapering handstones were common in all three strata, as were clay griddles.

During the season the museum catalogue was greatly amplified; many fine sculptures were repaired and placed on exhibit; and five new showcases were installed, containing pottery, ornaments, and skeletal material, among which is a complete skull with inlaid teeth, of the Early Acropolis period.

YUCATAN: UXMAL

S. G. MORLEY

Dr. Morley returned to Yucatan by way of Mexico City in September 1941. While

in Mexico City he delivered a lecture at the University Club, for the benefit of British war relief, on the archaeological investigations of the Institution during the past 25 years, and repeated the lecture in Spanish before the Sociedad Científica de Antonio Alzate.

During Dr. Morley's field work at Uxmal in the early part of 1941, a preliminary examination of the Great South Pyramid, a high, tree-covered mound southwest of the House of the Governor, revealed a section of a collapsed corbeled vault on the north or front side. This confirmed an impression, formed many years ago, that near the summit of this pyramid there had originally been ranges of rooms on each of the four sides. Dr. Morley devoted three weeks to excavations on all four sides of the pyramid, near the top, in order to establish the nature of the construction that had stood there.

The Great South Pyramid, the highest and largest at Uxmal, measures 96 m. north and south by 80 m. east and west, and is 27.5 m. high from the north base to the summit. It is built on a slope which rises from north to south, so that its base at the south is 4 m. higher than at the front. Two definite architectural periods were noted, and it is quite possible that the pyramid may contain still older constructions. The earliest building now visible consisted of a single range of at least four rooms, with long axes running east and west and doorways in their north walls. These were later incorporated into the northwest corner of the pyramid, their exterior back walls being covered by its masonry fill.

The pyramid proper was of eleven terraces, ten at the back because of the southward rise of the terrain. The terraces, 1.42 m. in vertical height, have battered faces. They are built of very roughly dressed stone like that of the substructure of the House of the Dwarf, and were finished

with a heavy coat of lime plaster. There were no recessed panels or other decoration on the faces of these terraces. A centrally placed stairway on the north side, 23.5 m. wide, projecting from the base of the pyramid and having about 70 steps, gave access to the uppermost terrace, which was also reached from the back by a somewhat narrower stairway, asymmetrically placed and in two offset flights.

On the highest terrace is a platform, 1.32 m. high, all four faces of which are decorated with an elaborate sculptured mosaic, the principal elements being the lattice pattern and the familiar Maya grecque. The platform is ascended by relatively narrow stairways of five steps each, at the north and south. On the platform, and built around and against a solid central core on the top of the pyramid, are four ranges of rooms; that on the front or north side seems originally to have consisted of five nonconnecting vaulted chambers entered by doorways in their north walls. The east, south, and west ranges, however, were almost entirely solid, there being only a single vaulted room at the middle of each; the long ends of all three, so far as could be determined, were of solid masonry. These four ranges of rooms are 6 m. high.

At some later time, a second outer tier of three vaulted rooms had been built in front of the three middle rooms of the north range. When these were added, the floor level of the old middle room was raised 1 m. above the floor level of the new chamber in front of it. The 1 m. from the floor of the outer middle room to the sill of the doorway of the inner room was sculptured with a magnificent Maya mask 3.25 m. wide and 1 m. high, which is in a perfect state of preservation. Indeed, it seems probable that the level of the inner middle room was raised expressly to provide a surface for the presentation of this

panel, which closely resembles the mask panel in an identical position in the middle outer room of the palace at Kabah.

The solid central core of the pyramid, surrounded by these four ranges, rises another 1.70 m. above the level of their respective roofs. There seems never to have been any construction on its summit, nor any stairway ascending to it from the level of the sculptured terrace which supported the rooms.

As a second major constructional undertaking, the pyramid was covered from bottom to top with a layer of rubble 1.5 m. thick, much of it composed of dry-laid, large, irregularly shaped pieces of limestone. The surface of this rough covering, completely enclosing not only the stucco-faced, terraced pyramid and sculptured upper terrace but also the elaborately ornamented façades of the four ranges of rooms, would also seem to have been terraced, though these later terraces are much broken down.

A possible reason for the encasement of the pyramid and its superstructure may have been that the sculptured façades of the four ranges of chambers had begun, soon after they were built, to fail, to crack and bulge outward so seriously that it became necessary, in order to keep the whole upper part of the pyramid from crashing down, to give it the support of added masonry, especially at the top where it could sustain the falling façades and prevent them from pushing outward. Incidentally to these operations, the ranges of rooms were filled solidly with dry-laid rough rubble, and the entire construction was converted into a great new pyramid, the main stairways on its north and south sides still being retained. It is probable that eventually this larger pyramid would have served as substructure for some sort of building had not final collapse of the Maya in the thirteenth and fourteenth cen-

turies halted this grandiose project before its crowning structure could be erected.

Owing to the burial of the elaborately sculptured façades of the building near the top before they had been exposed to much weathering, the façades were in practically perfect preservation. The north façade bears an intricate mosaic in both the upper and lower zones, in which panels decorated with geometric designs, grecques, and so forth appear. On the east, south, and west the upper zones only are decorated, the lower zones being of plain dressed stone.

Such is the beauty of the mosaic, the grace of the proportions, the size and commanding height of this pyramid, that it must, in its day, have been the most arresting building in the city.

As nothing like complete excavation could be attempted in the time available, only such trenches were dug, on the four sides and at the four corners near the top, as would permit the making of ground plans and elevations. The style of architecture indicates that the building was erected at the very height of the Puuc period, perhaps during the twelfth or thirteenth century. Some associated ceramic material was found, and two human skeletons, the bones and crania gone to powder.

In addition to the work on the Great South Pyramid, the Northwest Group was entirely bushed, and a map and north-south cross section were made. This group has some of the earliest masonry found at Uxmal; the flat building stones are only very roughly dressed, and in some cases extend clear through the walls; both exterior and interior surfaces undoubtedly were plastered.

Dr. Morley left Yucatan April 8, 1942. He delivered the Benjamin Franklin Medal Lecture before the American Philosophical Society at Philadelphia April 23,

and is spending the summer at Santa Fe, New Mexico, where he has had summer offices at the Laboratory of Anthropology for many years.

### YUCATAN: POTTERY

G. W. BRAINERD

The present study of Yucatecan ceramics was begun in December 1939. The year 1940 was spent in Yucatan in the classification, tabulation, and illustration of the extensive sherd collections gathered during the previous work of the Institution (Year Book No. 39, pp. 270-274); 1941 in Cambridge in making chronological studies from previous notes, in comparative work on museum and published material, and in preparation of the material for publication.

The analysis of the pottery collections showed that an overwhelming percentage of these belong to two major periods, neither of which can be accurately dated in either the Christian or the Maya calendar, and which together represent the relatively short part of the span of human occupation in the Yucatan Peninsula characterized by the building of the more imposing of the standing architecture. The two major periods represented in the material excavated previous to this study can be identified with (1) the major buildings in ruins of the so-called Puuc region—Sayil, Labna, Kabah, and Uxmal—and the earlier buildings at Chichen Itza; and (2) the later, or "Mexican," buildings at Chichen Itza. These periods will be called "Puuc" and "Mexican" respectively for ease of reference. In addition to these main groups, pottery referable to all the Peten periods was represented in various collections but without definite stratigraphic association with the native pottery. At Chichen Itza there were stratigraphic evidences of a later ceramic period, the pot-

tery of which equates with isolated fragments and specimens from widely separated localities in Yucatan. A considerable number of distinctive groups of fragments occur in collections which could not be placed chronologically from the collections on hand last year. The collections made from Oxkintok in 1940 produced a large sample of pottery stratigraphically proved to antedate the Puuc period and inferentially associated with the earlier style of Oxkintok architecture (E. M. Shook, *Revista mexicana de estudios antropológicos*, vol. 4, no. 3), in which a lintel dated 9.2.0.0.0 was found.

This year's program was planned to supplement the available material to such an extent that a general chronological sequence, including the total span of pottery making on the peninsula, could be built up and its major periods described. It was also hoped that the completion of such a span would allow it to be dated with regard to the Maya calendar, the Christian calendar, or both, thus furnishing material to aid in the correlation of the two calendars.

The field work during the present season has consisted of five trips which together occupied approximately three months. Each group of ruins investigated was sampled by ten to twenty trenches distributed throughout the site. From one to five of these were usually found to contain large stratified deposits, the analysis of which served as the key by which the other collections from the site could be identified. The best sources of large, stratified deposits proved to be cenotes whenever these were present near the ruin. Since the end of the field trips the greater part of the collections has been classified and tabulated, and illustrations have been prepared for about half the material. Mr. R. E. Smith spent several days



in Merida in the examination of this year's collections, making available to the study his thorough knowledge of Peten pottery typology. The tentative results thus far obtained will here be presented in the order of excavation.

Yaxuna was visited. A previous sample excavated from this site, though small, shows a large variety of pottery types and considerable Peten contact. The larger collections obtained on this trip permit the definition of four distinct periods, characterized by changes in the basic wares. The first period can be equated definitely with the pre-Old Empire period in the Peten. The second seems to equate with early Tzakol in the Uaxactun chronology, but stylistically shows closer similarities to Early Ticoman pottery of the Mexican highlands. The third period appears to have been contemporaneous with later Tzakol and Tepeu I at Uaxactun. The last period equates with the pottery of the Puuc, or the earlier great building period at Chichen. A sculptured stela and a sculptured jamb were found and notes, drawings, and photographs made. Additional mapping was done on the site. Work of this sort was conducted at each site visited, including sufficient mapping to locate all pottery trenches accurately.

The site of Dzibilchaltun has not previously been reported upon. It lies 1 km. south of the hacienda of the same name, and about 15 km. north of Merida. It consists of an aguada with a near-by ruined colonial church standing in the center of a Maya plaza. The site was suggested by Professor Alfredo Barrera Vasquez as a likely source of early colonial pottery. In addition to such pottery, several large groups of ruins, two partially standing Maya buildings, about 2 km. of causeways, and 22 stelae (6 of which were sculptured) were discovered and mapped.

Measured drawings were made of the Spanish buildings and of remains of frescoes in the church. At one of the buildings a dubious sculptured date of 1593 was found, which, however, is given some support by a date of 1617 discovered at the architecturally similar church of the neighboring village of Chablekal. Mr. E. W. Andrews took notes on the Maya architecture and stelae, including plans and sections of the two standing buildings. The pottery from the Maya ruins consists of a small collection of pre-Old Empire sherds, a large collection which seems immediately to antedate the pottery from the Puuc area, and a small collection of a period contemporaneous with the Mexican period at Chichen Itza.

At Acanceh the best sherd collections obtained came from the base of the pyramid which is surmounted by the building bearing the well known stucco façade (Eduard Seler, *Die Stuckfassade von Acanceh in Yucatan*, *Sitzungsberichte der Königlichen Preussischen Akademie der Wissenschaften*, vol. 47, pp. 1011-1025, Berlin, 1911). The collections have not been sorted as yet, but are known to contain material ranging from pre-Old Empire times through the Mexican period. The pottery resulting from Mr. Andrews' clearing of the buildings surmounting the pyramid may allow these buildings to be fitted into the ceramic succession. A preliminary check of the material indicates that collections deposited after construction of the building with stucco façade antedate the Puuc period.

A large quantity of pottery was excavated from Mayapan, and a collection was obtained from the cenote of the near-by town of Telchaquillo. The Telchaquillo pottery is all post-conquest. The Mayapan collection contains small groups of pre-Old Empire and Old Empire Peten, and of Puuc period pottery from the bottom

of a trench sunk in the mouth of a cenote. Above this shallow deposit, pottery of the Mexican period of Chichen occurred mixed with, and finally superseded by, a deep deposit of redware of later date. A series of trenches dug near buildings throughout the main group of the ruin produced collections in which late redware preponderates. Several of the buildings have since been cleared and mapped by Mr. Andrews. The redware found at Mayapan corresponds to redware of the latest occupation of Chichen Itza, an occupation which at the latter site left little pottery and few if any architectural remains. The Mayapan deposits contain a fine orange ware which is stylistically the immediate descendant of the "X" type fine orange found at Chichen Itza (G. W. Brainerd, *Revista mexicana de estudios antropológicos*, vol. 5, nos. 2, 3).

The final field trip of the season was made to Ticul, Dzan, and Mani. Modern pottery making was studied at Ticul, and excavations were made in the environs of the three towns. Classification of the extensive collections made is as yet incomplete. The town cenote at Mani yielded a sequence ranging from a horizon to which we have thus far recognized no affiliations, through pre-Old Empire, through the Puuc and later periods, into heavy post-conquest deposits. Deposits on the grounds of the historic Mani church and monastery present an extensive Spanish colonial sequence, ranging from vessels closely related in form and ornament to Dzibilchaltun specimens, up to modern times. These collections are rich in Mexican and European glazed wares, and we hope for accurate dating of the associated native wares from this part of the sample. Other excavations chiefly in chultuns in Dzan and Mani and near Ticul yielded samples of the Mexican, Puuc, and later redware periods, of which samples from this part

of the country were previously lacking in our collections.

A summary and discussion of the chronology in its present status may be set down here, always qualified by the unfinished nature of the work and by the sparsity of samples over the large areas covered. During the periods above called "pre-Old Empire" the Yucatan Peninsula formed part of the range of a more or less homogeneous culture, extending over a large area which included the Peten. A major part of our Yaxuna pottery of this period was accepted by Mr. Smith as very similar to the Uaxactun pottery. The Yucatan collections contain pottery of this kind from almost every large site sampled. Certain pottery types in the Yucatan sequence which may tentatively be equated with early Tzakol show definite similarities to central Mexican pottery of the Early Ticoman period. The Yucatecan periods which equate with Tzakol and Tepeu I vary throughout the peninsula, having but a minority of their elements in common with each other and with the Peten. Peten polychrome tradewares occur in small percentages, and stand out sharply from the native wares. The period herein called Puuc follows the above and is characterized by the dominance of slateware, the antecedents of which appeared in the preceding periods. This period is quite uniform throughout Yucatan, as are the following periods up to the conquest.

An interesting side light on pre-Old Empire architecture is furnished by the contents of three trenches dug in the lower slopes of a large pyramid (15-20 m. high) at Yaxuna. The trenches were so dug as to pass through only post-constructional refuse and post-occupational slump. The pottery, beyond a few late surface sherds, is exclusively and typically of the pre-Old Empire period. Yaxuna, with its evidences

of long and early occupation and its suggestion of influence on Chichen Itza (S. G. Morley, Carnegie Inst. Wash. Pub. 501, pp. 546-547), should certainly repay excavation.

Our large collections from the Puuc region sites of Labna, Sayil, and Kabah contain no pottery equivalent to that of the Mexican period at Chichen Itza. Uxmal contains only a small fraction of 1 per cent. Thus these sites must have been abandoned before, or at the time when, the so-called Mexican period reached Chichen Itza. North of the Puuc hill range near Ticul, however, as well as north of Merida, and at Mayapan and Chichen Itza—widely separated sites—the Mexican period is represented. The rise and major occupation of Mayapan coincided with the decline of Chichen Itza. This fact is proved beyond reasonable doubt by stratified deposits at the two sites.

The collections on which we have worked until now contain no deposits dating from the transition between the Mayapan and the colonial periods. The color and finish of the earliest colonial slipped ware in our collection and that of the Mayapan pottery are very similar, but there are various changes in forms between the two periods. The small collections we have seen from Tulum definitely belong to the Mayapan period. Tulum was probably occupied at the time when the first Spaniards saw it (see S. K. Lothrop, Carnegie Inst. Wash. Pub. 335, for a discussion of the evidence). Tradition places termination of the occupation of Mayapan at about 100 years before the conquest (Diego de Landa, *Relación de las cosas de Yucatan*), and the ceramic evidence certainly does not refute such a dating.

As can be seen from the above data, the purpose of this season's work is on the way to accomplishment. We have every

reason to believe that by the end of the year a ceramic sequence equating with the Peten ceramic sequence and extending to the colonial period in Yucatan will be available from the material already excavated. In addition, a re-examination of the long-held theory that the major cultural development of Yucatan coincided with the decline of the Old Empire has been made advisable by the increasing evidence that Yucatan supported a considerable, widespread, and culturally advanced population during and before the time of the Maya Old Empire, and that this population in most cases used the same architectural centers, even the same pyramids, as did the people of the heretofore emphasized New Empire. There is no evidence of a major break in Yucatecan pottery tradition between the times of the Old and New Empires, and certainly no evidence of a sudden influx of Peten Old Empire influence during this period, when a migration either cultural or physical into Yucatan has been thought to have occurred.

The pottery collected this season has added several new wares, and extensive data on form and decoration, to the known Maya ceramic repertory. Perhaps more important have been the stratigraphic data which have permitted the chronological placing of many kinds of pottery previously known only from isolated sherd samples and whole pieces. Data on the variation between samples of the same ware gathered from various localities have added to our knowledge of cultural distribution and exchange. The continuance of the policy of placing the architecture in the ceramic chronology by its accompanying pottery has been made possible in several instances this season through the work of Mr. Andrews on three of the sites included in this report.

This study should represent but the be-

ginning of more intensive and illuminating work. It has not been conducted as an end in itself, but as a tool to aid in the unraveling of the broader aspects of prehistory in the Yucatan Peninsula. The necessarily involved and time-consuming work now nearing completion should permit the approximate dating, or at least the placing in an anchored chronological sequence, of any ruin, standing or fallen, in the area. Only two of the six Yucatecan pre-conquest periods tentatively outlined in this report are at all well known, the Puuc and the Mexican. Architectural work on the immediately preceding and following periods has recently been begun by Messrs. Pollock, Shook, and Andrews.

The present ceramic sequence is merely a dating outline. The order of the periods described has been stratigraphically proved, but much could be gained by further study of developmental changes between the periods, cultural interconnections, regional variations, and craft techniques. Further ceramic studies should go hand in hand with the archaeological excavation necessary to furnish a complete picture of the several horizons, the chronological placing of which has been indicated by this survey.

#### YUCATAN: ARCHITECTURE

E. W. ANDREWS

It is curious that the most heavily populated and geographically best-known section of the Yucatan Peninsula has remained almost entirely unstudied by the archaeologist. The ruins on the low plain to the north of the Puuc hills and to the west of Chichen Itza are represented in scientific literature by only the briefest references.

During a stay in Yucatan from December 1941 through June 1942, Mr. Andrews carried out preliminary studies at ten

ruined sites within a radius of 40 km. from Merida. At three of these, Mr. Brainerd undertook stratigraphic excavations for pottery, and at certain others surface collections were made and subsequently examined by Mr. Brainerd.

Perhaps most interesting of the season's finds was a group of sites indicating widespread architectural activity in northern Yucatan during early Old Empire times. These illustrate a style of temple architecture rigid in itself and distinct from the elaborate patterns of later pre-Mexican construction on the northern part of the peninsula. The chronological separation of the distinctive early and late styles is attested by actual superposition of buildings, the occurrence of transitional forms, and the association of distinct pottery types with the two architectural styles.

The early architecture is distinguished by a special structural technique. Wall masonry is of large, roughly faced blocks, leaving little or no space for cement hearting between the two faces. Vaults are of deeply tenoned flat slabs, apparently never pre-shaped, set in roughly corbeled courses with much fine rubble and cement. Wall faces are evened with considerable spalling, but vault faces are composed entirely of it, as the crude ends of the flat slabs offer no regular surface. Wall and vault surfaces were finished with a thick coat of plaster. Neither wall nor vault shows any suggestion of veneer.

The form achieved is both constant and simple. Basal moldings either are absent or are composed of a single course of rough blocks. Medial and superior moldings consist of a single rectangular member. The upper façade is normally covered with stucco designs in deep relief, which often extend onto the moldings. Carved stone is never used in façade decoration.

Later pre-Mexican architecture of the region is characterized by the use of very

finely squared and faced stone in a thin veneer over a rubble core, both in wall and in vault. No spalling was needed, and a thin coat of plaster sufficed to form a very smooth surface. Basal moldings, usually complex, are almost universal. Medial and superior moldings follow a three-member pattern, the upper and lower elements triangular in section. The upper façade is characteristically heavily adorned with mask panels or a variety of designs made up of a mosaic of small carved elements; where stucco relief is found, it is secondary.

Excavations in a small section of the acropolis at Acanceh revealed that the famous temple with the stucco reliefs belongs to the earlier pattern. It was originally built close to the north edge of a truncated pyramid about 8 m. high. Later, the platform was extended some 60 cm., and a new face added to the pyramid, the sides of which were covered with white stucco and painted with designs in red. A further stage of construction extended the platform a considerable distance farther north; and on this addition, some 50 cm. above the original floor level, was built the long, narrow building facing the Stucco Temple. The new edifice, although retaining the essential block-wall and slab-vault structural technique, varied somewhat in external form. It stood on a 35-cm.-tall, single-member basal molding, and although retaining the simple rectangular medial and superior moldings, replaced the strongly retreating upper façade of the Stucco Temple with a taller vertical one. Excavation showed that during the use of the court between these two structures, the floor level was raised five times. Finally, both temples were filled with rubble, their doorways were sealed with masonry of the early type, and the entire area was filled in to the level of the roofs to serve as foundation for buildings in the later architectural style. This

final phase is represented by no standing rooms on the acropolis, but is evident from an abundance of carved stone façade ornaments, typical veneer wall blocks, finely cut, deeply tenoned vault stones, and full-width doorjambs. Associated with each of the developmental phases mentioned were sealed deposits containing potsherds which should be correlatable with Brainerd's more extensive stratigraphic material from the slopes of the acropolis. A preliminary examination indicates the probability that all stages through the filling-up of the court between the two early temples belong to pre-Puuc times. It is probable, moreover, that the large pyramid in the city plaza, originally covered by a later structure but now considerably exposed, also belongs to the early horizon. Visible fragments are characterized by the use of inset stairways, rounded, inset corners, a lack of finely cut stone, and the use of large panels of stucco relief. The plan is strongly reminiscent of that of early Peten substructures.

As early as 1911, Seler suggested that the buildings at Acanceh were earlier than those generally known in Yucatan. He also pointed out a strong resemblance between Acanceh architecture and that of Ake and Izamal to the north, and suggested that the latter sites might be assigned to an early period. Acanceh and Ake, both large ruins, are conspicuously ignored in the conquest-period historical traditions of the local natives. Landa states in regard to Izamal, "There is no remembrance of their builders and they appear to have been the first." During the present season, brief visits were made to Izamal and Ake. The majority of remains at both sites are definitely not in the Puuc tradition, which is easily recognizable even in the debris of wholly fallen buildings. Nor do they consist of the entirely uncut stone whose use followed the abandonment of

fine veneer in Yucatan. Substructures and, in some cases, buildings were made of great, roughly faced cubical blocks differing only in size from those of Acanceh and other early sites. The stucco decoration of the Izamal pyramids is remarkably similar to that of the mound in the plaza at Acanceh. Finally, Brainerd states that sherds from below the plaster floor of one of the final additions to the mound complex south of the Convent of San Antonio at Izamal are referable to the basal-flange horizon in the Peten. This reference is paralleled by the orderly distribution of ruins at Ake around rectangular plazas, an arrangement characteristic of the Peten sites but not found in the cities of the Puuc and Mexican horizons in Yucatan.

Evidence that these differences are chronological rather than geographical is to be found at Cuca, 10 km. east of Ake. Here the remains are entirely of buildings in highly evolved Puuc style with no trace of the megalithic or block construction discussed above.

Ten days were spent at the ruins of Dzibilchaltun (also locally known as Xlacah), 15 km. north and slightly east of Merida, where Brainerd was conducting ceramic excavations. One standing temple there belonged clearly to the early style both in structural technique and in external form. But a number of minor traits hinted a possible developmental transition to the Puuc style. The structure had a low basal molding, and the wall stones were more finely cut than those of Acanceh, although showing no tendency toward veneer. The spring course of the vault was of very carefully faced stone, in strong contrast with the rough slabs of the vault itself. The end walls carried a thin false vault spring, a characteristic of Puuc architecture found in neither of the early temples at Acanceh. Pottery from between two floors

in one of the rooms has been tentatively described by Brainerd as immediately antedating that found in the Puuc sites. This earlier architecture seems to have included the greater part of the construction at Dzibilchaltun. Visible fragments of a filled-in and almost completely buried structure in another part of the site show identical masonry and outer façade form, and indicate that at least large parts of an elaborate stucco façade similar to that at Acanceh remain intact under later construction. Other lower wall and vault fragments are in this tradition, and the general plan of the site is characterized by Peten-like aggregations of mounds around orderly plaza systems. However, a few carved façade stone elements strongly reminiscent of Mexican-period Chichen Itza art bespeak at least some later occupation. These remains are very common in a single court at the eastern edge of the site, and rather rare elsewhere. Although a number of glyphic stelae are too badly damaged to offer any hope of translation, it is clear that none carried Initial Series.

About 40 km. west and slightly south of Merida and 6 km. southwest of Kinchil are the ruins of Tzeme, a very large site, covering several square kilometers. A large part of the town of Kinchil and the neighboring hacienda of Santa Maria has been built with stone taken from its monuments; and two grotesque life-size human statues from Tzeme have been removed to the Merida Museum. Although no standing buildings remain, two periods of occupation are evident. At the center of the site is a group of tall pyramids around a rectangular plaza. Near by are several groups of lower pyramids similarly arranged around smaller plazas. Atop these mounds are vestiges of small structures in the block-wall and slab-vault tradition, entirely lacking carefully cut stone. In the center of the plazas, however, and scat-

tered outside the central area are numerous remains of distinct rubble-and-veneer structures with carefully squared full-width jambs, specialized vault blocks, and a variety of sculptured façade elements. These buildings clearly belong to either the Puuc or the Chichen Mexican period.

Reports were received of the small site of Chuhku, about 15 km. southeast of Tzeme, containing at least one well preserved standing temple. Many residents of Kinchil can serve as guides.

Through the kindness of Don Fernando Cervera, it was possible to spend a number of days at the large ruins on the Hacienda Yaxcopoil, 25 km. south and slightly west of Merida. The ruins, about 1500 m. east of the hacienda buildings, seem to have been occupied from very early times through the Puuc and Chichen Mexican periods. Although no excavation was undertaken, much pottery from the latter periods was found on the surface. A small amount of red lacquer ware may indicate a short overlap into the last phase of pre-Spanish culture, or a small continuous population in that era. The central group of ruins is distributed around a long, narrow plaza, at one end of which is a pyramid approximately 12 m. high, ascended by four stairways. Atop the complete ruin of the superstructure is a geographical bench mark with the legend  $N 20^{\circ} 45' 05''$ ,  $W 89^{\circ} 42' 18''$ . This large mound is called Tanmul, meaning "Central Pyramid," by which name the site is occasionally known. Present superstructure debris in the central group is characterized by a quantity of veneer stone, but this may be of secondary origin. About 250 m. south of this complex is a large, low platform mound bordered by four ranges of rooms surrounding a central court. Several rooms of the northern range are still standing and locally called Aka'na ("House in the Dark"), by which name the whole site has also

been known. Several phases of construction are apparent. An original five-room structure was built in style clearly transitional between the early and Puuc periods. The lower walls are faced with a poorly cut, irregular veneer, but the vault is made of flat, almost unfaced blocks so crudely set that the face consists largely of spalling. Moldings are complex but still rectangular in section, varying in form as a support for elaborate panels of deep relief in painted stucco which cover the upper façade zone. There is no carved stone. In two later stages, a series of rooms was built around this unit in a very different manner. Their rubble walls bear a thin veneer of finely cut, beautifully squared stone laid in perfect courses. Vaults are of the characteristic "boot-shaped" and beveled blocks, equally carefully set; and the upper façade zone was covered with panels and masks in carved stone mosaic. The outer corners bear on each face a line of carved rosettes from medial to basal molding. The doors, simple in the interior structure, become triple, with jambs and round pillars carved in typical Puuc style. The Aka'na will richly reward future excavation, for in the construction of the later rooms, the stucco façade of the older temple was carefully sealed in and remains largely intact. Remains of the later Puuc period architecture are distributed generously over the site, as are those of the following era of Mexican influence. Several long, low mounds bear a central row of altars formed of crudely cut megaliths, and have no trace of further masonry superstructure. Another common form of building is the round-columned, flat-roofed colonnade of Mayapan type, whose walls (as at Mayapan) are of crude block rather than veneer masonry. This fact, in connection with the small amount of red lacquer ware in surface pottery, indicates Yaxcopoil's importance for future study as pos-

sibly spanning the gap between the veneer tradition of the Puuc and Chichen Mexican periods and the uncut block masonry which later replaced it. This possibility is not known to exist at any other site on the peninsula.

Minor excavations were undertaken at one further ruin apparently occupied in pre-Puuc times. This site, 500 m. east of the Merida-Uxmal highway at Kilometer 39.5, is on the hacienda of Sihunch'en, whose name it has been given. Recently there were a number of standing buildings, but these have been in large part demolished and their stone ground up to resurface the near-by highway. Fragments of two buildings were left, both of which seem to be in the earliest architectural tradition. Walls are of large, coarse blocks with no rubble fill, vaults of the familiar unprepared flat slabs. No basal molding was used. Medial and superior moldings were one-member and rectangular. As usual, a lack of cut stone accompanies an elaborate stucco façade, in this case largely fallen. One building had but a single long, narrow room, colonnaded in front with very crudely rounded stone columns without pedestal but with a roughly squared capital, on which rested very crude stone lintels. The total door height was only 122 cm. Masonry in both buildings is much cruder than any observed elsewhere during the present season. It may reflect relative antiquity, or merely a lack of architectural skill at this small site. Not enough pottery was found to offer much clue to dating, although a few sherds were of pre-Mexican slate which could be assigned to either Puuc time or slightly before.

Another period of Yucatan history came under study in the course of a month's work at the ruins of Mayapan. Eight buildings were either largely or entirely cleared; and a number of minor excavations served to round out the picture thus

obtained. The site and its surrounding wall were mapped by Patton in 1938 (cf. Year Book No. 37, pp. 141-142).

A minor early occupation of the site is indicated by a number of re-used, finely cut stones in the buildings of the central group. No structures of this period remain, however, although it is possible that an unexcavated interior building immediately below the present superstructure of the Pyramid of Kukulcan (Structure 10) may belong to that horizon. These remains probably correspond to an underlying stratum of pottery (about 8 per cent of the whole) found by Brainerd to be similar to that of the Mexican period at Chichen Itza.

The vast majority of remains at the site consist of small unit shrines and colonnaded palace-type structures employing either thin-drummed round columns or anthropomorphic supports for flat beam-and-mortar roofs, as did a few atypical structures whose plans were almost certainly copied from Chichen Itza prototypes. The resemblance of the large round tower at Mayapan to the Caracol at Chichen has often been mentioned. The latest superstructure of the great pyramid at Mayapan is identical in plan with the Chichen Castillo, although very differently constructed and with unvaulted roof. Two small round temples excavated had ground plans similar to that of the Casa Redonda at Chichen.

Except where a few stones were re-used from the earlier period mentioned, both walls and vaults at Mayapan were constructed of completely uncut, rough blocks, with no tendency toward veneer. No prepared outer face is recognizable on blocks in fallen debris, and the absence of cubical form made coursing next to impossible. Although no façades at Mayapan stand as high as the medial molding, it is evident from debris that the profile was



normally that of a single two- or sometimes three-member molding with restricted upper zone, and the elaborate carved stone mosaic so typical of earlier-period façades was absent.

The major occupation of Mayapan may be clearly assigned to a period later than that which at Chichen Itza is represented by the architectural efforts seen at the ball court, Castillo, Temple of the Warriors, and related structures. But certainty as to whether architectural effort had entirely ceased at Chichen during the Mayapan period must await the discovery of specific associations between certain late structures at Chichen (the Temple of the Initial Series, the Temple of the Interior Atlantean Columns, etc.) and deposits of pottery from one of the two periods. Although certain of the larger temples at Mayapan undoubtedly drew inspiration for their plan directly from Chichen, the constructional techniques of the two sites are uncompromisingly distinct. The earlier veneer traditions persisted at Chichen through the end of architectural activity. On the other hand, the relation between Mayapan and the cities of the east coast of Yucatan is unmistakably close. Structural techniques are almost identical, and parallels in external form are striking. Both groups emphasize the colonnaded palace with round columns and anthropomorphic roof supports; and the simple unit shrines which form a large part of the structures in the two groups follow closely the same plans. The lack of carved stone façade decoration in the two areas parallels the restriction of the upper façade zone and simplification of the molding pattern. Other details such as walls surrounding the cities (Mayapan, Xelha, Tulum) imply further connection. It will be seen in Brainerd's report that available ceramic evidence equally strongly indicates that the so-called "Mexican period" remains at

Chichen Itza form a horizon earlier than that of Mayapan and the east-coast cities.

The above considerations suggest that the conventional division of peninsular culture into a "Maya period" and a "period of Mexican influence" by no means delineates the significant phases of its development. In the evolution of art, architecture, and ceramics, three quite different divisions seem clearly indicated by data now available:

I. The earliest architecture in Yucatan is characterized by walls of large, crudely faced blocks, vaults of flat, entirely unprepared, corbeled slabs, and a complete absence of carved stone façade decoration. Rough wall and vault faces were smoothed by a thick coat of stucco, which was also used in the execution of elaborate reliefs in the upper façade zones. This period of occupation is seen at Coba in the east, and is strongly represented in the Merida region. Pollock and Shook have described contemporaneous and very similar architecture at sites running from Maxcanu in the Puuc to Bakna in central-western Campeche. Brainerd characterizes associated ceramics by absence of evolved slateware, and affinities with Tzakol and perhaps Tepeu I in the Peten. The lower limits of this occupation are at least as early as the end of cycle 8.

II. Sometime in the second half of cycle 9, a drastic change took place in north-peninsular culture. From block-wall and slab-vault architecture, there was a sudden transition to rubble construction covered by only a thin veneer of finely cut stone. The simple external building form gives way to the complex but rigid patterns associated with the architecture of the Puuc region, where the new forms may have developed. The stucco façade was replaced by elaborate panels of carved stone mosaic. Along with this change in architecture came an equally striking development of

slatewares in pottery; the earlier wares disappear, and ceramic resemblances to the Peten are confined to tenuous similarities to Tepeu. This new culture does not seem to have been of foreign introduction, for the new architectural and ceramic forms had their origins in the previous period. Early in cycle 10, continental Mexican influences appear at Chichen Itza, either coincidentally with or shortly after the abandonment of the Peten cities and those of the Puuc. During the so-called Mexican period at Chichen Itza, these influences altered the superficial aspects of local culture, but notably failed to affect to any extent the fundamental architectural, sculptural, or ceramic techniques. Architectural innovations are seen in such features as replacement of the basal molding by a battered lower zone, and the prominent use of serpent columns and stairway balustrades. But the basic construction of rubble buildings with a thin stone veneer remained unchanged until the abandonment of the site. New religious motifs in sculpture accompany no great change in style. Finally, although imported trade pieces make their appearance in connection with changes in shape and design in local pottery, slatewares maintain undisputed dominance.

III. The second great change in Yucatan culture took place about the middle of the fourteenth century, and was quite as radical as the first. Veneer was abandoned, to be replaced by the use of uncut, rough blocks in a masonry more similar to that of modern native houses than to any earlier archaeological remains. Vaults are made of crude masonry, but are no more frequently used than the flat beam-and-mortar roof. A new temple form, the unit shrine, becomes numerically dominant. The colonnaded palace, which first appeared late in period II, takes on new form. Columns become universally round

rather than square, and anthropomorphic roof supports are common. In sculpture, forms appear which bear little resemblance to previous artistic efforts of the Maya. In pottery, the slatewares vanish, to be replaced by what Vaillant called "red lacquer wares" and (perhaps later) crude figurine incensarios. The new architectural forms persisted for the century and a half or two centuries until the Spanish conquest.

#### GUATEMALA: KAMINALJUYU

E. M. SHOOK, A. L. SMITH

In 1936 and 1937 excavations were carried on at two mounds of the great archaeological site of Kaminaljuyu in the outskirts of Guatemala City (Year Books Nos. 34-36). One of the mounds (A) was completely dissected. It proved to contain eight superimposed structures and to overlie six pit tombs rich in pottery and jades. The body of the second mound (B) was not investigated, but three tombs were found below its frontal platform and a modern cut on one side indicated the probable presence of several structures built, as in Mound A, one above another. In the course of preparing the results of the above work for publication, it became obvious that more data were needed on several important points concerning architectural and mortuary practices. It was therefore decided to excavate Mound B, a task undertaken by Mr. Shook and carried out from November 1941 through May 1942.

The mound before excavation was a conical hillock some 35 m. in diameter by 7.5 m. high. A vertical slice had been cut, in recent times, from its western slope; and, some years before, a deep, wide trench had been run in from the southeast by treasure hunters. Mr. Shook's opening trenches were pushed inward from the

north and south, these sides being chosen because the later structures in the mound were known to face west, and it had been learned, during the work on Mound A, that tombs and caches, stairways, and other important architectural features were to be found on the front and could more safely be reached by lateral than by frontal approach. The south trench at once encountered the basal step of a pyramidal substructure of puddled clay faced with a layer of lumps of pumice and coated with *piedrin*, an almost concrete-hard mixture of lime and small pebbles. The trench was pushed through this, revealing a second building of identical construction, which in turn was penetrated as far as a third building of pure adobe. There was thus disclosed a sequence corresponding to that found in Mound A, whose two outermost elements had pumice-and-clay heartings with *piedrin* finish, the third being of adobe.

At this point it was felt that enough was known of the mound's make-up to permit the frontal features to be investigated. The basal step of the outermost building (Structure 5 in the final enumeration) was accordingly followed around the southwest corner and across the western face to its abutment against the remains of the frontal stairway. The basal step was also located on the north and followed around the northwest corner to the stairway. The same method was employed in outlining Structure 4, and in laying bare the south side of the adobe pyramid, Structure 3. At the same time a third penetrating trench was run in from the east, encountering and passing through two more adobe structures, Nos. 2 and 1.

As to Structures 1 and 2, little was learned, for they were seen only in median section in the sides of the narrow penetration trench. They appeared to have

been low pyramids, parts of which had been cut away in the course of building the later units of the complex. Structure 3, however, was relatively well preserved. It was an adobe pyramid with basal measurements of about 30 by 30 m., a broad adobe stairway with heavy balustrades mounting its western face. The upper part of the stairway had been destroyed by the pot-hunters' trench, but a small area of the summit platform remained.

Structures 4 and 5, though inferior in construction to the corresponding units of Mound A, yielded the hoped-for information as to the pumice-and-*piedrin* type of building. It was learned that it had a low basal step, a lower sloping zone topped by a slab-supported cornice, and a more nearly vertical second zone divided by moldings into rectangular panels. At the front a stairway mounted to a jutting platform, on which there apparently was located a small shrine. A second flight, of which only traces of the lowermost steps remained, led upward, doubtless to a temple on the summit platform.

Two tombs were found: a small one south of the foot of Structure 5's stairway, and a very large one in front of the foot of the stairway of Structure 3. The small tomb contained the skeleton of an aged male, the bones of a child (probably a sacrifice), some jades, and a number of pottery vessels. The large grave was evidently that of an important personage, as it was more lavishly stocked with mortuary equipment than any of the other ten tombs so far opened at Kaminaljuyu. The principal occupant, seated cross-legged in the center of the tomb floor, had been literally covered with ornaments of jade and shell; a necklace of 280 jade beads was about the neck. In front of the body was a pile of very fine pottery, many of the pieces coated with stucco and beautifully painted. The skeletons of three young

persons, evidently sacrificed at the time of their master's burial, lay toward the walls of the tomb. Near one of them was the finest single object recovered, a pyrite-incrusted plaque whose slate backing bore an intricate carving, the central elements being two small figures standing on either side of an altar, from which rises what appears to be a conventional tree.

Although the finds in this tomb were most spectacular, the most important results of the Mound B excavation were the data recovered as to architecture and as to the succession of pottery types. Great numbers of sherds were found in the fill. These were largely of the Esperanza phase, contemporaneous with the erection of the structures, but among them were many fragments of Miraflores pottery. The latter, representing the oldest ceramic horizon so far identified at Kaminaljuyu, had, of course, been scraped up with earth used for the fill of the various structures. After the mound had been abandoned as a place of worship and had fallen more or less into ruin, there accumulated on and about it a heavy stratum of occupational debris containing pottery of two post-Esperanza phases which have been called Pamplona and Amatlé. Although stratigraphic conditions were not clear, there is little doubt that Amatlé is the older of the two. One component of the Amatlé phase is plumbate ware, mostly in simple cylindrical forms. Similar plumbate was found in 1940 by A. L. Smith at San Agustín Acasaguastlán on the Motagua River, and more came to light in J. E. S. Thompson's excavations of the past season at El Baul on the Pacific coast plain. When these and other ceramic materials from highlands and lowlands have been studied and compared, it seems probable that the chronological and commercial relations of several important ancient Guatemalan cultures will become clear.

During the mapping of Kaminaljuyu in former years there had been noted at least nine constructions which, because of their elongated rectangular form, were surmised to be ball courts. In order to test this supposition, A. L. Smith, in 1941, ran a trench across the middle of one of the largest. The finding of two tenoned stone parrot heads, analogous to those of the Copan ball court, and of traces of sloping benches paralleling a playing alley settled the matter conclusively.

During the past season further excavation was carried on here, and two smaller courts were investigated. The original 1941 trench in the large court was reopened and sunk to a depth of about 5.5 m. before sterile natural deposits were reached. Directly below the northern long wall, Mr. Smith exposed parts of two deeply buried earlier constructions. The upper one was of red-painted adobe, apparently with low vertical terraces. Its upper parts had been cut away in ancient times. An adobe floor, also painted red, extended outward from its base. Farther down was the southeast corner of a very well preserved building, probably a substructure. Its basal terrace had borne siab-supported moldings, torn away when the building was buried, but it, and what remained of a second terrace, were still covered with smooth, hard, red-finished piedrin. Well underneath this was a floor of packed adobe, under which, to subsoil, a distance of nearly 2 m., the deposit contained only Miraflores pottery, the earliest type so far found at Kaminaljuyu.

By the time subsoil had been reached, the rainy season was about to begin. Work was therefore suspended, but the trench was fenced and left open in case it should be possible to push the operation farther at some future time. Although removal of the tremendous overburden would be a long and costly undertaking, the investiga-

tion of the early buildings and of what may well lie below and behind them would undoubtedly yield invaluable archaeological information. We already know that there is a direct superposition of three types of structure and a stratification of Miraflores, Esperanza, and Pamplona-Amatle pottery. Because of the depth of the deposit and the sealing of several of its horizons by floors, there is likelihood of recovering unmixed samples, some of them perhaps exemplifying hitherto unknown transitional ceramic periods. Furthermore, the lowest floor may be connected with a structure dating from Miraflores times. The discovery of such a building would be of the greatest interest, for Miraflores structures, presumably ancestral to all later architectural developments in this region, are still entirely unknown.

While work in the deep central trench was going on, a pit was sunk in the southwest corner in a vain search for the tenoned stone head which, on the analogy of the Copan ball court, should have been found there. The digging, however, revealed, below the level of the court, a piedrin floor pierced by several large postholes, which indicated the former presence there of a building of perishable materials.

The second ball court investigated formed part of a small group just to the east. A trench was dug across its short axis, a little north of the center in order to cut into a mound resting on the western wall of the court. The upper part of the wall and the face of the mound proved to be terraced and to bear a piedrin coating.

The transverse trench, again carried to subsoil, yielded evidence of a long series of structural events, involving two rebuildings of the court; an abandonment during which a humus layer was laid down; and the excavation, perhaps through a still earlier fill, of a pit in whose bottom was a drain, slab-floored and -walled but with-

out capstones. A tenoned human head of stone came to light in the western extension of the trench.

The third court lies in a considerable group well to the east in a district called La Granja, where a real-estate development is now being undertaken. As part of the "improvement" a road was run through the court, cutting both end walls and passing down the long axis of the playing alley. This permitted observation, with relatively little digging, of the enclosing walls and the alley. The dimensions of the alley were determined to be 33 by 7 m. Remains of an earlier construction were laid bare. This, razed almost to ground level when the ball court was built, had originally been a multi-chambered affair without supporting platform. In its piedrin floor were postholes and on it were butts of several free-standing walls of moldmade adobes faced with pumice blocks and piedrin.

A number of finds were made at this court. Directly under the southeast corner of the playing alley were two plain redware bowls set lip to lip, probably a dedicatory offering. Near the center was a large tenoned stone snake head, which had obviously slipped down from the north-central wall. Several other heads and pieces of broken sculpture had come to light during the digging of the modern road. In the center of the court Mr. Smith encountered a filled pit which, seeming to be ancient, was believed to have served as a drain or sump. Well below the level of the playing alley, however, were the almost completely rotted bones of a horse, and below them the crushed remains of two pottery water jars. The horse bones, of course, proved the pit to be post-conquest, but their condition argued for very long burial, and the jars, when restored, were found to be of an unknown type, per-

haps ancestral to present-day Chinaulta pottery. They are, in any case, the oldest "modern" vessels so far collected.

To sum up: Mr. Smith's investigations made it clear that the nine or more long rectangular constructions at Kaminaljuyu are ball courts, and have permitted identification as such of many similar ones at other sites throughout the valley of Guatemala. The ball court, indeed, is shown to have been perhaps more abundant in this region than in any other part of Middle America. As to the details of construction, data are as yet not fully satisfactory because, being of pure adobe, the courts have suffered severely from erosion and the growth of forest trees. It is known, however, that the playing alley was long and narrow, and that it had low, sloping side benches. It was closed at either end, thus lacking the expanded end zones characteristic of most other ball courts. Set opposite each other at the middle of the parallel side walls were two tenoned stone heads, usually parrot or snake, often with a human face in the open mouth. Whether these were placed vertically, as at Copan, or horizontally is unknown, as all were found fallen forward on the side benches. There was no evidence of stone markers in the floor of the playing alley. The courts seem to be sited without regard to the cardinal points.

#### GUATEMALA: PACIFIC COAST

J. E. S. THOMPSON

The considerable number of fine sculptures in the neighborhood of Santa Lucia Cotzumalhuapa, Escuintla, on the Pacific slope of the Guatemalan highlands, are of prime importance in determining the history of Mexican-Maya relations. The style, subject matter, and hieroglyphs of the monuments have long been recognized as of a distinctly Mexican cast, but the

chronological position of this Mexican enclave has been a matter of much speculation. The ruins have usually been attributed to the Pipil, a Nahuatl-speaking group, a part of which was settled in eastern Escuintla at the time of the conquest, but the question of when these sites flourished could not be solved without excavation.

At the end of January 1942, Mr. Ralph L. Roys, Mr. Thompson, and his photographer, Mr. William Webb, made a tour of the central and western parts of the Pacific coastal slope to decide on a place to excavate and to inspect sites and collections with a view to obtaining information on the general archaeological picture in this area. The most interesting outcome of this reconnaissance was the discovery of two stelae at a large site on the Fincas San Isidro Piedra Parada and Santa Margarita, near Acintal, in the southeast of the department of Quetzaltenango. Both stelae were carved in the easily recognizable style of Izapa (Tuxtla Chico), a site in southeastern Chiapas. One of them, however, had an Initial Series introductory glyph followed by the number seven, expressed by means of a bar and two dots. There was a plain surface immediately below, indicating that the number had not been associated with a glyph, but the rest of the surface has flaked off. This stela, therefore, falls into the small and very perplexing group of monuments which have numbers but no glyphs, and which, in the opinion of some archaeologists, are of extreme antiquity. It is difficult to hazard whether the complex scrollwork of this Izapa type denotes the over-elaboration of a primitive style or the sophistication of a late rococo development. Near by was a boulder carved with a kneeling figure, perhaps a ball-game player, in the style commonly known as Olmec. The site is large, and because of the diversity of styles

(there is also extremely crude sculpture there) and because plumbate sherds indicate that its occupancy may have been extended, excavation there might be well repaid.

Following this preliminary reconnaissance, Mr. Thompson and Mr. Webb proceeded to El Baul, a sugar plantation near Santa Lucia Cotzumalhuapa, where through the courtesy of Mr. Carlos Herrera, one of the owners, and Mr. Julio Garcia Salas, the manager, they were invited to stay as guests of the plantation as long as the excavations lasted. El Baul is of archaeological importance because among the sculptures found there is the Piedra Herrera, another of the group of stelae with numbers unattached to glyphs. This has been read as an Initial Series recording the very early date 7.19.7.8.12. It was desired to determine whether ceramic evidence bore out this early attribution, and it was also hoped to date the Cotzumalhuapan sculptural style, of which good examples also occur there, in terms of ceramics.

Considerable quantities of sherds were obtained, but, unfortunately, no clear-cut stratification. Two periods are, however, represented, and there are slight traces of a third. The latest, which includes plumbate vessels of simple forms, but not those which found their way in trade to remote parts of Middle America, appears to be coeval with the Amatle horizon at Kaminaljuyu. The earlier is close to the Esperanza horizon of Kaminaljuyu. There were also a very few sherds which stylistically belong to the still earlier Miraflores horizon. One pyramid was partially excavated, bringing to light a very fine low-relief sculpture in Cotzumalhuapan style which represented the upper half of a deity or personage emerging from the body of a rather realistic crab. This pyramid also yielded two heads of snakes in the round,

a stone with the date 4 Quiauitl, the glyph being represented by a full-face view of the head of Tlaloc, and a stairway of large, well dressed stone blocks. The pottery has not yet been studied in detail, but at least it can be said that among the very few sherds in the soil in front of and level with the butt of the Piedra Herrera are included some which are very probably of the later horizon.

Pottery from Tiquisate, Suchitepequez, is almost exactly the same as that of the later period at El Baul, and other sites on the Pacific coastal slope have several ceramic types in common with El Baul. At the site of El Castillo, about 1.5 km. from El Baul, the presence of round monolithic columns was noticed. Some of these were in the soil at the foot of a mound, others had been set up around the hacienda building. Visits were paid to the neighboring fincas of Pantaleon, Los Tarros, Aguna, and Xata, where archaeological material was inspected. The many examples of sculpture at Pantaleon are well known, but it is not generally realized that some of these pieces came from El Baul and neighboring fincas.

Mr. Thompson spent the month of April in Guatemala City making notes on the sherd material from El Baul in order to avoid the necessity of shipping the collection. One interesting point has developed, namely, that the sherds of plumbate ware, many of them poorly fired, it would seem, are of forms such as shallow bowls and simple cylindrical vases. None are of the more elaborate effigy vessels or composite silhouette jars which are so widely distributed. Since Mr. Kidder found a similar situation in the Amatle horizon at Kaminaljuyu, and in view of the associated pottery at both sites, it seems not improbable that these simple forms of plumbate are anterior to the development of export to distant markets.

During a brief reconnaissance in the highlands, in company with Mr. Roys, two important groups of ruins near Sacapulas were visited. One, Rio Blanco, on the peninsula formed by the confluence of the Blanco and Negro rivers, was found to have an oval pyramid and a ball court in a good state of preservation. The second, Chutix Tiox, situated on a steep hill to the north of the Santa Cruz Quiche road and about 4.5 km. from Sacapulas, has some remarkably well preserved buildings, including a *monoztli* (a small pyramid-like platform) with the plaster still in position on most of the almost perfect surface, and a room about 24 m. long, the back wall of which was standing to a height of about 2.7 m.

#### NICARAGUA

F. B. RICHARDSON, K. RUPPERT

As was recorded in the last annual report, tracks of barefooted human beings and of various animals and birds are from time to time found during quarrying operations in a deeply buried volcanic stratum at El Cauce in the vicinity of Managua. In 1941 Mr. F. B. Richardson investigated a recently discovered set of these footprints. The layer in which they occur was the product of an eruption from some vent on higher land. From it a sheet of semiliquid mud flowed down toward Lake Managua, and while this was in process of hardening, but still plastic enough to receive perfect impressions, the people and animals passed across it. Almost immediately thereafter a fall of dry cinders covered and preserved the tracks. Subsequently the area was blanketed by other mudflows, now, like the footprint stratum, hardened to stone. Later the entire series of layers was cut through by a small stream whose bed, in course of time, became filled with silt and water-rolled

boulders. Still later there was a heavy fall of pumice, followed by an interval of quiescence with further stream erosion, deposition of humus, more pumice falls, and, finally, a cessation of volcanic activity and the deposition of the present topsoil to a depth of 1.25-1.50 m.

That a long time must have elapsed since the making of the footprints is certain; but until the volcanological studies of Dr. Howel Williams, of the University of California, who is cooperating with Mr. Richardson in this investigation, can be carried farther, no estimate of the period involved is possible. In the meantime, however, Mr. Richardson has continued work at the site, and Mr. Karl Ruppert devoted the past season to study of the archaeological remains found in the recent surface deposits.

The area of the original discovery was widened and the tracks were followed for a distance of some 20 m. A careful count showed that 17 persons had passed, going in a straight line toward a low promontory that juts into the lake. The tracks originally identified as those of deer have since been shown to have been made by a large peccary.

Another discovery of animal prints, made during the past season, promises to be of great interest, both archaeologically and paleontologically. At a stone quarry on higher land some distance away there has been exposed a sequence of mudflows, apparently from the same source as those of El Cauce. The lowest of these, which may well represent the identical flow seen at the base of the El Cauce series, was found by Mr. Richardson to contain tracks of a large cloven-hoofed creature. Latex casts were submitted to Dr. Thomas Barbour, of the Museum of Comparative Zoology at Harvard University, and to Dr. Paul O. McGrew, of the Field Museum in Chicago, both of whom identified the



prints as those of bison, an animal which seems never before to have been reported from Central America.

If man and bison, an animal certainly long extinct in the region, are found to have been contemporaneous, we shall have evidence of the high antiquity of the El Cauce footprints, which may indeed be the oldest traces of human occupancy yet found in Middle America. It is therefore outstandingly desirable to gain even the smallest scrap of knowledge as to the culture of these people. The prospects of such a discovery are, however, remote, as the surface on which they lived now lies buried under several meters of solid rock, pumice, and earth and is accessible only in the few relatively tiny spots where quarrying operations have removed the overburden. The vicinity of the footprints is not promising, as the pre-mudflow land thereabouts was a gentle slope, apparently an open and perhaps barren plain. As such it would have been ill suited for a dwelling place, and the chances of finding artifacts on it are very slight. But since the government drainage ditch made it possible to reach part of the old surface at one side of the footprint area, it seemed worth while to expose and search as much of it as was reachable. Some 60 m. of footprint stratum were accordingly removed and the top 30 cm. of the underlying deposit passed through a fine-meshed screen. Nothing, unfortunately, came to light.

Through the good offices of President Somoza, the site has been acquired by the Government of Nicaragua and a resident custodian has been appointed. Over the tracks Mr. Richardson has erected a permanent building, whose tiled roof protects them from the weather while its open sides permit their examination at close hand.

Although determination of the age of the footprints is primarily a volcanological

problem, a minimum date, archaeologically speaking, can be arrived at through study of the cultural remains in the superficial deposits, for the oldest of these must be much younger than what lies under the great accumulation below. Mr. Ruppert therefore devoted the season to surface excavations at El Cauce and elsewhere in the neighborhood of Managua.

The pottery-bearing level of brown soil at El Cauce is 3 m. above the footprint stratum, varies in thickness from 1.3 to 1.6 m., and, according to Dr. Williams, "while apparently of aeolian origin, much must have been laid down by running water." A number of pits and trenches were dug and yielded abundant sherd material apparently of a single not very remote period.

During the previous season a burial ground had been discovered east of El Cauce and south of the railroad tracks. In some of the boot-shaped jars were fragments of human bones. The area was re-examined during the current season. Although a number of caches of vessels were uncovered, none contained skeletal material.

A high point of land northwest of El Cauce protruding slightly into the lake seemed a likely place for a series of trenches. The yield of sherds was extremely small. In general the wares are similar to those from El Cauce. The number of sherds worked as net-sinkers was relatively large. Sherds obtained from trenches at Las Mercedes Airport, 9 km. east of Managua, were again of wares similar to those from El Cauce.

At the close of the season a mound to the east of El Cauce, on the property of Don Salvador Salgado, was examined. A pit in the top of the mound is said to have been made by pothunters. A trench on the north side extending from the valley floor inward to the center disclosed a rough stone-faced platform 50 cm. high

and 6 m. wide. The mound, 3.50 m. high by 10 m. in diameter, resting on this platform was faced with unworked stones. Near the center and 2 m. above its base was a cache of three vessels. The sherds, varying little from those at El Cauce, did however include several pieces of Usulután pottery, a ware which, in Guatemala and El Salvador, is found only in the earliest ceramic horizon. The presence of Usulután fragments, probably dating from a period long anterior to the erection of the mound and owing their presence there to accidental inclusion in its fill, argues for a relatively ancient occupancy of the Managua valley subsequent to the latest volcanic activity.

Analysis and interpretation of the ceramic material have not yet been made. A wide trade in pottery vessels is, however, attested by the presence of sherds of Honduranian (Ulúa Valley and Lake Yajoa) and Salvador wares. Over 75,000 sherds were examined and sorted, and a representative collection will be brought to the United States for final study.

#### CERAMIC TECHNOLOGY

ANNA O. SHEPARD

The study of plumbate ware has been the principal project of the year. This ware, important because of its wide distribution in Middle America and its consequent value for correlating occupations and establishing contacts, has for nearly 60 years been an archaeological enigma. The place of its manufacture is unknown, and postulates regarding that center have included such distant regions as Salvador and southwestern Chiapas. From the standpoint of ceramic technique it is the most highly developed Middle American ware known, yet its peculiarities have been completely misunderstood and erroneous speculations have gained acceptance

through frequent repetition. Technological analysis is therefore required. The ware also affords opportunity for a somewhat different approach from that which has been made in previous technological studies of Middle American pottery. In earlier work, pottery recovered from a single site has been analyzed for the purpose of defining occurrences. A considerable amount of time has therefore necessarily been devoted to the study of local wares of inferior quality which had no trade value and which consequently do not directly contribute to investigations of the interrelations of peoples. In the plumbate project, on the other hand, attention is concentrated on a highly specialized and widely traded ware. All its geographic occurrences and ceramic associations are being studied. We are considering the indications which paste gives of the place of its manufacture, the degree of variation in the materials used and the possibility of admixture of clays, the relative importance of firing method and properties of the clay in their effect on the quality of the surface, the frequency and method of imitation, the possibility of trade in raw materials, and the comparison of contemporaneous wares in composition and workmanship.

In this study it has proved advantageous to observe technological and stylistic traits simultaneously. The technological work has included analysis of the surface material, thermal experiments to learn what methods of firing were employed, and petrographic analysis of the paste. In the study of surface material, spectrographic analyses have been made of 15 samples, together with comparative analyses of 25 samples of common red slips. We have been fortunate in having the privilege of using the 35-foot grating spectrograph of the Massachusetts Institute of Technology. X-ray analyses of several samples have also

been made, by courtesy of Drs. Grim and Bradley, of the State Geological Survey of Illinois. These results, together with those obtained by microchemical determination of the three major constituents, definitely correct the idea that the vitreous appearance of the ware results from a lead glaze. The analyses also explain in large measure the distinctive surface qualities of this most unusual pottery. Except for the single analysis by Loeb in 1903, made before the development of refined methods of handling small samples, these are the only analyses ever made of the glaze material.

A series of firing experiments has been conducted to learn what temperatures and firing atmospheres would produce the peculiar hard, gray surface of the ware. Soft, red, underfired portions of plumbate sherds have been changed to the typical hard, vitreous surface in these experiments.

Because of the extremely fine texture of the paste, petrographic analysis has been more exacting and time-consuming than has that of other wares. The 150 sections studied are from several sites in the western Guatemalan highlands, and from Alta Verapaz, Salvador, and Chichen Itza. Various sherds thought to be either of mixed material or imitations have also been analyzed. The paste is distinctive in composition and unquestionably offers the best clue to place of manufacture of the ware.

In spite of the great importance of plumbate, its stylistic features have never been fully described, partly because published studies have, in general, been based on small collections. In order to correlate stylistic and technological features and to compare them with those of contemporaneous wares, it has been necessary to obtain from many sources the available data on style. This stylistic material will be included in the final report on plumbate. A record has been made and photographs

have been obtained of the plumbate vessels in the principal museums of the United States. Over 250 vessels are now represented in the file; the record includes profile drawings and detailed measurements from which basic proportions have been calculated, and data on surface qualities and workmanship. To facilitate the analysis of style, drawings have been made by Miss Janice Snow of incised designs, and such details of effigies as features and objects of adornment. The mass of stylistic data which has already been collected, when extended by field studies in Central America, will, it is hoped, serve to corroborate and strengthen the results of technological analysis.

#### SOUTHWESTERN UNITED STATES

E. H. MORRIS

Three seasons of field work among early Anasazi remains near Durango, Colorado, have been described in Year Books Nos. 38-40. Preparation of a report on these excavations and the objects exhumed has been the principal objective of Earl H. Morris and his collaborator, Robert F. Burgh, during the current year. This report has developed into a far longer undertaking than was anticipated. It is the aim of the authors to present the various categories of material from the Durango excavations in as thorough detail as they did for Anasazi basketry in their publication (*Carnegie Inst. Washington Pub.* 533) which came from the press in December 1941. To that end the specimens are being studied with extreme care, and the archaeological literature of the Southwest and neighboring areas is being combed for references which will shed light on the occurrence and distribution of the types into which they fall. There are several months more of work ahead before the report will be ready to submit to the editor.

During the 1941-1942 school year Mr. Burgh devoted part of his time to the teaching of courses in Southwestern and classical archaeology in the University of

Colorado. In the same interval Mr. Morris spent a number of weeks upon archaeological manuscripts submitted to him for opinion and revision.

## SOCIAL ANTHROPOLOGY AND LINGUISTICS

R. REDFIELD, S. TAX, A. VILLA R.

The program in ethnology and social anthropology this year consisted of desk work rather than field enterprises. *The folk culture of Yucatan*, a book by Dr. Redfield summarizing the results of the research carried on in Yucatan from 1931 to 1936, was published in July 1941. Dr. Tax completed his report on the economy of the Indian community of Panajachel. This will form the first of three volumes on that community. The other two volumes are in preparation: that dealing with the Indian world view is about half done; that concerned with the social organization is in its inception. Dr. Tax also wrote a short article on race relations in Guatemala, prepared a short manuscript—to remain unpublished until further developed—dealing with what appear to be important differences between highland and lowland Maya cultures, and organized materials on Middle American ethnology in connection with a course on that subject which he and Dr. Redfield taught in the spring at the University of Chicago. At the end of the year, Dr. Tax left for Mexico City, where he was to teach a course in Maya ethnology, with special reference to ethnographic field techniques, at the Escuela Nacional de Antropología. It is his plan, following the termination of the course, to take a group of students to the Tzotzil community of Zinacantan in the state of Chiapas, to do field work in that little-reported Maya group. For these purposes the services of Dr. Tax have been lent by the Carnegie Institution to the Escuela Nacional.

With the assistance of their class at the University of Chicago just mentioned, Dr. Tax and Dr. Redfield began a collection and comparison of material on Middle American ethnology which might ultimately become a contribution to a handbook on that subject. It is planned also to prepare a selected bibliography.

Sr. Alfonso Villa R. spent most of the year in revision of his manuscript on the Quintana Roo Maya, which is now ready for the press. In May, Villa reached the small Tzeltal community of Dzajalchen in the municipio of Oxchuc, near Tenejapa, in Chiapas, with the intention of remaining there several months carrying on a general ethnological study of these Indians, who had been the subject of a brief published report based on a reconnaissance of their villages made by Villa in 1938. His first report from the field contained maps and censuses of the community chosen for study and information on social organization. Of interest is the fact he reports that each settlement takes its name from a cave wherein is housed a cross at which members of that settlement perform their religious rites; each tract of land in the settlement is considered the permanent property of this cross; the son (never a daughter) inherits the land with obligation to keep up the prescribed rites, and sale of a tract does not change its belonging to the traditional cave.

Sr. Juan Rosales, field assistant to Dr. Tax, spent the year in Chicago, continuing the preparation of his monograph on the culture of the Maya of San Pedro de la

Laguna in the midwest highlands of Guatemala. He was aided by support from the Rockefeller Foundation. He has completed the introduction to his work, and the chapters on technology and material culture, comprising almost 500 typescript pages. He will remain in Chicago at least until January 1, 1943.

As was recorded in the preceding annual report, Benjamin Paul, a fellow of the Social Science Research Council, went to San Pedro de la Laguna to study the same community investigated by Rosales, as an experiment in ethnological method. Mr. Paul spent a year in that village, and returned to the United States in December 1941. Having received funds from the University of Chicago to enable him to prepare his report, he set about this task at the beginning of the new year. Mrs. Paul, who accompanied him and did field work under provision made by the Committee for the Study of Dementia Praecox, Scottish Rite Fund, brought back unusual and interesting material on the socialization of the child.

A further contribution to the ethnological work of the Institution was made by the University of Chicago when it supplied a sum of money enabling Rachel Reese Sady to make a study of certain official Mexican records, with an evaluation of their usefulness to ethnologists. Mrs. Sady examined and, when necessary, transcribed or summarized the formal records made by national, state, and municipal governments pertaining to two communities known to contain a large Indian element but differing in most other respects. She then did enough field work in the first community (Ocotopac, in the state of Morelos) to enable her to form a judgment as to the extent to which conditions therein were reported in such records. The other community was one in Chiapas to which it is expected Dr. Tax will go in

the winter of 1943. Mrs. Sady is writing a report which it is expected will be a guide, for the investigation of Mexican aboriginal communities, to students who may wish to take advantage of formal governmental records as a part of their work.

Beginning July 1, 1942, the program of field research will be strengthened as the result of an important addition to the Division staff. Through an arrangement with Duke University, Dr. John P. Gillin, of that university, has become a Research Associate of the Institution and a participant in its program of social anthropology and linguistics. Dr. Gillin is to spend the summer of 1942 initiating studies among the Pokoman of eastern Guatemala. This group, concerning which there is almost no information, was briefly visited by Dr. Redfield and Dr. Tax in 1941. Dr. Gillin has been informed as to the special interest this Maya group have for the general project, with regard to their critical position in connection with the supposed dichotomy of the Maya peoples into lowland and highland divisions, their interest for students of Indian-Ladino relations, and the possible interrelation of market systems, or their absence, with other elements of Indian society. Dr. Gillin will, however, develop his research along such lines as seem most promising after his preliminary survey.

Melvin Marvin Tumin, a student of anthropology at Northwestern University, received a fellowship from the Social Science Research Council to enable him to acquire field experience in Middle American ethnology. This he will do in the eastern highlands of Guatemala, where his work will be supervised by Dr. Redfield.

While Mr. Samuel L. Bradshaw worked on the grammar of Yucatec left unfinished by Dr. Andrade at his death, Dr. Abraham M. Halpern continued the comparative

study of other Maya languages. His initial task was to examine and organize Dr. Andrade's field notes and to review all published materials bearing on the linguistics of the Maya and their neighbors, with a view to estimating the present state of the study and recommending a course to be pursued in carrying it forward. In the year just ended, Dr. Halpern went through the notes and catalogued the phonograph-

record material. With the kind assistance of Mr. Edward F. Sywulka, a dictionary file was started for the Mam language. A beginning has also been made on a comparative dictionary file. The work was discontinued when Dr. Halpern took leave of absence as of April 1, 1942, in order to undertake studies of an Oriental language important in connection with the war effort.

## POST-COLUMBIAN AMERICAN HISTORY

### HISTORY OF THE MAYA AREA

F. V. SCHOLES, R. L. ROYS

Mr. Scholes spent most of the past year in Albuquerque, New Mexico, with headquarters at the University of New Mexico. For several years the university, which is strategically located in an area which has strong historical and cultural ties with Hispanic America, has stressed Americanist studies, and in 1941 a School of Inter-American Affairs was created to give direction to this program. Mr. Scholes, who had been head of the History Department of the university prior to joining the Division of Historical Research of the Carnegie Institution, was invited to serve as Lecturer in History for the academic year 1941-1942 and to give a graduate course in the bibliography, methods, and problems of Spanish colonial history. Instruction in this course was given once a week for two hours throughout the year. Mr. Scholes also served at times as an adviser on problems relating to the general program of inter-American studies.

Research under the History of Yucatan Project was carried on as usual by Mr. Scholes and Miss Adams in offices at the university library. Progress was made in exploiting a large accumulation of archival materials from Spain, Mexico, and Yucatan, especially with reference to studies

being made in collaboration with Mr. Roys, and it is expected that these will be completed by the end of 1943. It was Mr. Scholes' intention to visit Yucatan between the first and second semesters of the university term, but this plan was abandoned early in December.

In October Dr. Chamberlain was granted leave of absence from the Carnegie Institution to permit him to accept an appointment as Senior Cultural Assistant at the United States Legation in Guatemala City. Consequently his work on the conquest of Yucatan has been temporarily suspended.

The employment of Sr. J. Ignacio Rubio Mañé terminated December 31, 1941. Since 1935 he had been engaged in archival investigations in Merida and Mexico City. As a result of his researches a vast amount of new documentary material relating to the history of the Yucatan Peninsula has been made available. In accordance with an agreement made in 1939 by Mr. Scholes and the officials of the Mexican National Archive, Sr. Rubio Mañé spent the past two years on an inventory of the Papeles de Bienes Nacionales section of the Archive, which contains almost 2000 bundles of ecclesiastical papers of the colonial period, notably materials for the archdiocese of Mexico City. The inventory, which Sr. Rubio Mañé completed in December, is

now available for use by all students of the colonial history of Mexico. Carnegie Institution wishes to take this opportunity to express its appreciation to the Director and other officials of the Mexican Archive for courtesies extended to Sr. Rubio Mañé and other members of the Division staff during the past few years, and to record its thanks to Sr. Rubio Mañé for his loyal service in connection with the History of Yucatan Project.

Much of the past year has been spent by Mr. Roys in the completion of a survey of the institutions and culture of the Yucatecan Maya during the period immediately preceding the Spanish conquest. New documentary sources discovered and made available by Mr. Scholes and a closer study of other Maya documents have been found to supplement and cast increasing new light on the published reports of the earlier Spanish writers.

Evidence is accumulating regarding a ruling class in Yucatan, apparently composed of families claiming to be descended from former Mexican invaders. This group not only controlled the political organization, but also monopolized the priesthood. Since a knowledge of hieroglyphic writing was confined to the priests and some other members of the nobility, we have an anomalous situation, in which the principal key to Maya science was in the hands of a class of allegedly foreign origin.

In contrast with conditions reported as widely prevalent in the highlands of Mexico, in at least four, and probably more, of the native states of Yucatan we find what appears to have been a genuine territorial government, in which the head of the principal town not only confirmed and controlled the heads of the other towns of his area, but also frequently put his own appointees into such positions. Although the local head acted in a judicial

capacity in his town, he was obliged to refer certain serious cases to the territorial ruler. Finally, the latter kept track of the boundaries of his state, inspecting them personally from time to time to prevent trespass on the part of aggressive neighbors. Other states, however, had no single ruler, but consisted of allied towns or groups of towns, in which the local head was likely to belong to the most prominent lineage group of the region.

A third point of interest emphasized by the more recently discovered source material is the extensive trade which existed between Tabasco, Yucatan, and Hibueras-Honduras, the last being the northern coast of what are now Guatemala and Honduras. Although the languages of the Maya stock largely spoken in all three areas were very similar, scattered Mexican-speaking colonies were also found in Tabasco and Honduras, which were especially active in trade. Notwithstanding such differences in language and culture as existed, commercial relations appear to have been so close that the three countries could well be considered a single economic area. Campeche people had trading posts on the Ulua River in Honduras, and the Chontal-speaking Acalans of southwestern Yucatan occupied an entire quarter at Nito, a famous commercial center near the mouth of the Rio Dulce. Generally speaking, the Yucatecan Maya exported cotton cloth, salt, honey, and slaves to their neighbors on either side and received in return metal objects, cacao, feathers, precious stones, and other luxuries. That these commercial relations created a certain community of interest is shown by the evidence of military alliances, which appear to have existed between some of the Yucatecan towns and those near the coasts of Tabasco and Honduras.

Many of the articles imported into Yucatan by way of Tabasco and Hibueras

came originally from the inland neighbors of the last two. Early in 1942 Mr. Roys went to Guatemala, where a study was made of the region in which Nito was said to have been situated, and of what appear to have been two of the most important natural trade routes into the interior. One was the Montagua River, on which merchandise could be transported by canoe to the foot of the rapids not far below Gualan. The other was the water route formed by the Rio Dulce, Lake Izabal, and the Rio Polochic. Passenger launches now operate on the latter from the sea to Panzos, beyond which the river is navigable for canoes as far as La Tinta. Cacao plantations were reported on both the Montagua and Polochic by the first Spanish explorers; and the maize land in the valley of the Polochic is still considered to be especially good. The navigable part of the Montagua furnished access to the Chorti country, and on the Polochic canoe traffic reached the Poconchi area and probably also the Kekchi. Regarding the Chorti, it is of interest to note that recent ethnological investigations indicate that their culture resembles that of Yucatan more than it does that of the western highlands of Guatemala (Year Book No. 40, p. 308).

Mr. Roys, in company with J. E. S. Thompson, visited a number of archaeological sites along the Pacific slope of Guatemala formerly occupied by Mexican-speaking immigrants. Many of these people were still living in various parts of the region at the time of the Spanish conquest, and a colony of them existed in central Guatemala. The language, known as Pipil, is still spoken in Salvador, but seems to have disappeared in Guatemala within recent years. Their sculpture has significance for the history of Yucatan because of its resemblance to that of the Mexican period in the latter country. In both cases, as Mr. Thompson has recently shown, var-

ious features of the culture reflected by the sculpture appear to have been brought from a common source in southern Veracruz.

Such analogies seem less noticeable in the western highlands of Guatemala, but here, as in Yucatan, native historical legends indicate that the ruling class believed itself to be descended from people who had come from the Gulf coast of Mexico. A considerable number of archaeological sites were visited in this region, particular attention being given to those which were occupied at the time of the conquest, among them Utatlan, Chuitinamit on Lake Atitlan, Iximche, Sacaleu, and Rabinal. The ruins of Rabinal are the best preserved, and its remains are imposing. Situated on a high, barren ridge above a large, fertile valley and well protected from attack by its location, the site consists of eight ceremonial plazas, two containing excellently preserved ball courts. One of the latter is set into the upper floor of a plaza which was laid out on two different levels. In each complex the most prominent buildings are a central temple and a long, narrow house at one end. Both are set on substructures and have walls of rough, flat stones laid in mud mortar but covered with a thick coat of lime plaster. The dimensions and general appearance of these buildings suggest that they had borne flat, beam-supported roofs. Although a number of house sites were observed on the slopes adjoining the plazas, the location is such that it seems unlikely that a large population resided permanently at the site.

At Salama, a short distance east of Rabinal, there was formerly a group of Mexican-speaking Indians, who have been completely absorbed by the local Ladino population. Two days were spent in questioning a number of the older people, who remembered this group, and a few of their Hispanicized descendants. It is of interest



to note that they were apparently little influenced by their Rabinal-Quiche neighbors. Although the latter, especially those of the near-by town of San Miguel Chicaj, have always visited the Salama market regularly, it is generally agreed that the local Indians had little to do with them.

Returning to the United States through Mexico, Mr. Roys visited Teotihuacan and Tula, the latter being of especial interest to the student of Yucatan because of the remarkable resemblance of the sculptures recently uncovered there to those of the Mexican period at Chichen Itza.

#### UNITED STATES HISTORY

L. F. STOCK, J. J. MENG

Volume V of Dr. Stock's *Proceedings and debates of the British Parliaments respecting North America*, a description of which was given in the last annual report (Year Book No. 40, pp. 310-311), was issued in the early autumn. Progress on the sixth volume of the series, which will begin with 1754, has not advanced to the point set for this year's work. As was to be expected, the war has greatly interfered with the normal use of the facilities of the Library of Congress. The Division of Manuscripts, in the hospitable shelter of which the work has been carried forward through all these years, was for a long time, pending its removal to new quarters in the Annex, closed to investigators. It was also found expedient to restrict the use of many of its collections, and to withdraw temporarily all stack privileges. The library officials, with customary kindness, extended every aid possible under the circumstances, but the emergency regulations have made it difficult to work with the materials at hand and impossible to put into final form the completed part of the manuscript for this volume.

Under these circumstances Dr. Stock has been devoting some time to the collateral reading of such documentary, biographical, and other works as will be useful for future annotation of the series or may contribute to the text. With the assistance of Mrs. Helen S. Tepper, he has also taken advantage of existing conditions to begin the organization of the files of the former Department of Historical Research. Under the direction of the late Dr. J. Franklin Jameson that department not only was engaged in a wider program of historical activities than at present, but also served as a clearing house for historical projects and inquiries. The correspondence, therefore, especially Dr. Jameson's remarkable letters, shows perhaps more than does any other existing collection the variety of American historical activities of those years. It is hoped that a collection of Dr. Jameson's letters will soon be published as an important chapter in the story of the development of American historiography.

During the year Dr. Stock has, as usual, answered many inquiries of students, and has placed at their disposal some of his parliamentary materials. He has served as chairman of the Committee on Publications of the American Catholic Historical Association and, as one of the latter's ex-presidents, on the Executive Council of that organization. In November 1941 he discussed the "Uses of government records" before the Federal Records Conference of the Society of American Archivists; and in December spoke before the Irish History Society of the District of Columbia on the "Transportation of Irish prisoners to the American colonies."

Work on the *Guide to materials for American history in the libraries and archives of Paris* was continued during 1941 and 1942 by Dr. John J. Meng under the

supervision of Dr. Waldo G. Leland. Volume II, dealing with the French Foreign Office archives, has been completed by the multilith process and is about to be released. Volume III is practically complete in manuscript form. This latter volume, originally planned to include only materials in the War Office archives, has been enlarged to include as well materials from the archives of the Comité de l'Artillerie, the Comité Technique du Génie, the Service Hydrographique, and the Ministry of Marine. The manuscript for volume IV should be completed before the end of

the calendar year 1942. It will include the Actes du Pouvoir Souverain relating to America, materials from the Archives Nationales, and a small amount of miscellaneous items from other depositories. The manuscript for the first part of this volume is now ready for the printer. The final volume of the series, volume V, will be devoted to the Archives des Colonies. Work on the manuscript for this segment, one of the largest and most complicated of the lot, will begin as soon as the earlier volumes are completed, probably by January 1, 1943.

## HISTORY OF SCIENCE

GEORGE SARTON

*Introduction to the History of Science.* The manuscript of the first half of volume III, dealing with the first half of the fourteenth century, is now complete, but is delayed to permit the inclusion of the many hundred additions and corrections which will doubtless be encountered in the writing of the second part (covering the latter half of the fourteenth century). Since the first half runs to some 3000 typewritten pages, the revision involves considerable work in itself. Two chapters (out of fourteen) of the second half are already finished.

*Editing of Isis.* Volume 33, the first pub-

lished in America, has been issued. It is the largest and richest volume in the history of *Isis*, comprising 740 pages with many illustrations and including 41 papers, 54 notes, 85 reviews, and a bibliography of 1400 items. On account of increasing expenses, the capacity of *Isis* has been much reduced. It has not yet been possible to renew the publication of *Osiris*, for which much material has accumulated.

The proofreading and editing of *Isis* are taken care of by Dr. Pogo, who also conducts many minor investigations entailed by the editing and by the *Introduction*.

## PUBLICATIONS

MARGARET W. HARRISON

The seventh volume of "Contributions to American Anthropology and History" (publication 528) has just been issued. In addition to Contributions 35 and 36, listed in the last annual report, the volume contains *Substela caches and stela foundations at Copan and Quirigua*, by Gustav Strömmsvik (no. 37); *The Maya calendar of the Ixil of Guatemala*, by the late J.

Steward Lincoln (no. 38); and *Rio Grande glaze paint ware: a study illustrating the place of ceramic technological analysis in archaeological research*, by Anna O. Shepard (no. 39). Three manuscripts are scheduled for early appearance in volume VIII: *The archaeology of southwestern Campeche*, by E. Wyllys Andrews; *San Agustín, Guatemala*, by A. Ledyard Smith and

A. V. Kidder; and *The wall of Mayapan*, by Ralph T. Patton.

Toward the end of 1941 the Institution published Morris Steggerda's *Maya Indians of Yucatan* (publication 531) by the multilith process. This sociological study is based primarily on the town of Pisté, Yucatan.

*Anasazi basketry, Basket Maker II through Pueblo III: a study based on specimens from the San Juan River country* (publication 533), by Earl H. Morris and Robert F. Burgh, came from press in December 1941. The authoritative work on Southwestern basketry, it is a report on the vast collection covering the formative period of Southwestern culture, the only culture north of Peru where perishable materials have been preserved. A study on the sites of Durango, Colorado, which will add to the knowledge of Basket Maker culture, is planned by Mr. Morris for early publication.

The manuscript of *The Xiu Chronicle* is now complete in two parts: part I, "The history of the Xiu," by Sylvanus G. Morley; part II, "The Xiu Chronicle," by Ralph L. Roys. It will not be microfilmed as was formerly announced, but has been deposited in the Peabody Museum of Harvard University. Mr. Roys has adapted much of his material in this manuscript for presentation as a separate monograph, *Colonial Yucatan*.

To the five numbers of the new series "Notes on Middle American Archaeology and Ethnology" already published have been added this year *The prototype of the Mexican codices Telleriano-Remensis and Vaticanus A* (no. 6), by J. Eric S. Thompson, and *Observations on glyph G of the lunar series* (no. 7), also by Mr. Thompson.

It is expected that September 1942 will

see the publication of *Archaeological researches in the northern Great Basin* (publication 538), by L. S. Cressman, of the University of Oregon, and others. The problem of the history of early man in this area has been approached by some dozen cooperating specialists in the fields of anthropology, archaeology, paleontology, geology, and climatology.

Now being edited is the large monograph *Archaeological reconnaissance in southern Campeche and northern Guatemala* (publication 543). The introduction, summary, and description of the ruins have been written by Karl Ruppert; the epigraphy, by John H. Denison, Jr.

With the cooperation of Carnegie Institution, the University of Chicago Press published Robert Redfield's *The folk culture of Yucatan* in October 1941. Two manuscripts also in the field of social anthropology are ready for press: *The Maya of Quintana Roo*, by Alfonso Villa R., and *The economics of Panajachel, Guatemala*, by Sol Tax.

The preparation of the typescript of volume II of the *Guide to materials for American history in the libraries and archives of Paris* (publication 392) is almost finished. This book will be reproduced by multilith and released in the late fall of 1942. The material, covering the archives of the ministry of foreign affairs, has been compiled by John J. Meng, who is nearing completion of the manuscript for volumes III, IV, and V. This is the last in the series of guides to the sources for American history in the archives of foreign capitals to be published by Carnegie Institution. The manuscripts of the guides to Scottish and Dutch archives have been deposited in the Library of Congress.

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## SPECIAL PROJECTS: HISTORICAL RESEARCH

MARION E. BLAKE, Bradford, Vermont. *Preparation of a monograph on ancient Roman construction based on the material accumulated by the late Dr. Esther B. Van Deman.* (For previous reports see Year Books Nos. 38 to 40.)

When the international situation made it clear that a return to Italy would not be possible for some years, it seemed advisable to change the plan for completing the work of the late Dr. Esther B. Van Deman on ancient Roman construction so that a volume could be ready for publication by the end of 1942. The scheme involves a cut through the two volumes proposed by Dr. Van Deman to present both the techniques and the historic background from the earliest times through the reign of Augustus. Five chapters have been prepared in accordance with the change of plan: "Squared stone construction in Rome and vicinity," "Sun-dried bricks," "Brick and tile construction," "Mortar," and "Concrete." Only two chapters remain to be written: an introductory chapter dealing with methods, based largely on Dr. Van Deman's preliminary articles,

and a concluding chapter giving in somewhat condensed form the chapters already written by Dr. Van Deman as the first part of her second volume. The chapters already covered by previous reports will have to be reorganized to fit the new plan. The inconsistencies and repetitions inevitable in a work carried on over a period of years will have to be eliminated, and all references carefully checked. Dr. Van Deman had to a certain extent chosen her illustrations from her large collection of personal photographs, but plates will have to be arranged and indexes made.

Whereas a final checkup in Italy would bring a greater precision in details, it would not, in Dr. Blake's opinion, change the essentials presented in this volume. At the present moment, it is impossible to tell whether the second volume can be written without a return to Italy.

## PALEONTOLOGY, EARLY MAN, AND HISTORICAL GEOLOGY

JOHN C. MERRIAM, President Emeritus, Carnegie Institution of Washington. (For previous reports see Year Books Nos. 20 to 40.)

In activities of the past year it has been the purpose first of all to carry to completion projects of research which have been under way, but for which it had been difficult to obtain opportunity for field work or for study of sufficient scope to permit ultimate judgments regarding the problems under consideration. As a second type of activity, effort was made to advance certain important researches requiring cooperation of a number of individuals with common interests, but working in somewhat different fields. By this method it was desired to guarantee the continuation of these researches over a longer period than would be possible for work of any one person. As a third objective, the attempt has been made to review certain philosophical problems of scientific and human interest which represent the focusing of ideas from many aspects of geological and paleontological science, and for solution of which there must be a broad foundation of investigation and experience.

In 1942 a considerable percentage of investigations of the first group, which had been taken up in 1938-1939, have reached a stage at which one may assume that their further advance is guaranteed by the interest and activity of associated or co-operating investigators. Of these a number may be considered as having reached a place at which the research and its results have already become a part of history in this field of science.

Certain studies of the second group have required either additional financial support for field and laboratory work, or more extended or closer cooperation among students and institutions. Some

of these researches have also reached a point at which it may be said that they are rapidly taking their places in the group of studies for which the major contribution is now completed.

The third group of investigations, growing out of the thinking and experience of Dr. Merriam, either independently or with his associates, has reached a place at which it becomes desirable to define and shape the problems more precisely than has heretofore been possible.

In organization of certain features of work during the past year it became clear that there rests upon students of scientific problems a larger responsibility than has heretofore been recognized for interpretation of research results in terms of human interest, such as may influence our study of major social and governmental problems. With shift in magnitude and degree of complication in world problems there has been wider search for materials which may aid in our attempt to understand questions involving different types of nationalities and different points of view.

More and more there has been a tendency to recognize relation between the underlying laws which control in nature and the principles in evolution of human groups and of ideas. The view that man has become largely independent of nature has been replaced by recognition of the fact that with all that has developed in creative activity and knowledge on the part of man, we are still largely imbedded in nature, from which we receive not only the physical and biological foundations upon which human evolution is based, but the influence also of laws which

may guide in formulation of social organization and of ideas.

COOPERATIVE RESEARCHES ON GEOLOGY AND  
HISTORY OF LIFE IN THE JOHN DAY  
REGION OF OREGON

As has been indicated in earlier reports, one of the most extensive and at the same time most fundamental of the fields of research in this program is that relating to the history of life and the geological story of eastern Oregon as represented in the region of the John Day River. Begun in 1899 through cooperation with members of the staff of the University of Oregon, these studies have been carried forward over forty-three years with very few periods of interruption. This research, though initiated under the direct guidance of J. C. Merriam, has come to include activities of a considerable group of workers, a number of whom were students or associates in the paleontological and geological laboratories of the University of California. Although these researches have been carried on in the main independently, at the same time they have been so related that there is not only understanding among the workers, but mutual aid also.

The researches under way in the John Day area have included the broad studies of geology by J. P. Buwalda in cooperation with all the other investigators where their work has touched geological problems specifically. In the field of the history of life, Chester Stock and E. L. Furlong have devoted themselves for many years to research on the mammalian faunas with reference to structure, classification, and that time succession in the geological record which gives the evidence of evolution. Studies of the invertebrate life, representing mainly Mollusca, have been carried out by E. L. Packard, of the State College of Oregon, on the basis of many years'

work in the John Day region and on other related faunas found in western United States.

Investigation of the great series of important and beautifully preserved fossil floras of the John Day region has been conducted for a long period by R. W. Chaney as a special project involving not only classification and sequence of the plant life of that region, but its relation also to distribution and evolution of other fossil floras in the later formations of North America, eastern Asia, and Europe. In these studies there has also been taken into consideration the relation of changes in plant life as represented in the evolution of fossil floras to distribution of floras of the world at the present time.

A phase of the study of the John Day region which has developed in recent years, and looks toward higher human utilization of the results and also preservation of the materials for future investigators or for public education, is represented in the project now being advanced for protection of a considerable part of the geological section of the John Day region. This is so planned that a nearly complete sequence of formations will be seen in spectacular scenic presentation, such as serves to impress the visitor or the scientist with the important features of the geological story.

*Researches of John P. Buwalda.* Dr. Buwalda has continued to have the leading part in research on geology in its relation to the story of the John Day region. As has been indicated in earlier reports, he has done extremely careful detailed mapping of several large areas, including the most important sections of the John Day region proper. On these maps there have been placed the data bearing upon areal distribution of the formations, geological succession, structure, and crustal movements, as well as the relation of the geological section to steps in the history of life.



As one of the significant problems of correlation involving relation of the John Day region to other geological sections in the Northwest, Dr. Buwalda has been engaged also in accumulation of data bearing upon the paleontologic and geologic relations of the Ellensburg formation of eastern Washington and of other strata which have been thought to be Ellensburg occurring in that region. Vertebrate fossils have been obtained from a number of localities. During the past summer, studies were carried out also on occurrences of somewhat similar beds in some of which Professor George F. Beck, of the Central Washington College of Education, has obtained vertebrate remains. Comparisons were made with the typical Ellensburg beds. All the sedimentary deposits described were found to be typically of nonmarine origin, and all rest upon the Columbia River lava series. Over large areas in central Washington the exposures seem to indicate that these beds are the approximate equivalent of the typical Ellensburg. But there are probably also some younger formations in that region. The beds in White Bluffs, long thought to correspond to the Ellensburg and to be of Miocene age, have been known for some time to be Quaternary.

Dr. Buwalda noted a peculiar and as yet unexplained circumstance in that the Ellensburg formation of central Washington, of Upper Miocene or later age, and the Mascall formation of central Oregon, of Middle Miocene age, seem to bear the same relation to the Columbia River lavas upon which they both lie. It would be expected that the Ellensburg, presumably younger than the lavas, would lie either disconformably or nonconformably upon them. Several well exposed contacts of Ellensburg sediments upon lavas were examined with a view to determining the relations, but in each case the evidence

points to conformity. The stratification of the sediments at each locality is sensibly parallel to the uppermost lava flow, and commonly the upper flow still bears scoriae and flow breccia, suggesting that virtually no erosion of the lava surface occurred before it was buried by the sediments. It is also significant that the Ellensburg deposits contain very little basaltic material.

Dr. Buwalda has also examined a number of localities at which structure of the sequence of formations might be expected to give additional light both on the succession of geological stages in the John Day region, and on relation of the John Day geological sections to those of eastern and central Washington. These sections, such as that on the Columbia River between Roosevelt, Washington and The Dalles, Oregon, have given important information on the sequence in age of the deposits. Other studies, such as the examination of fault structure in the Picture Gorge Quadrangle and the mapping of structure in the Cretaceous of the Mitchell Quadrangle in the John Day region, have furnished extremely important data bearing upon the whole question of sequence of deposits and their structural relations.

Dr. Buwalda has also studied carefully the wonderfully exposed geologic section along the John Day River between Spray and Dayville with a view to considering possible inclusion of that region in the proposed park or parkway reservation. Consideration was given to the width of the territory to be included, to the features which would have largest interest and stimulus for the public passing along the highway, and to the dangers which would beset this scenic district if it were not protected in some form of reservation. Dr. Buwalda believes that the entire district from Spray to the Mascall Ranch should be included in the area which it is proposed to protect. Fortunately, since the

present activities of the population in that region are mainly agricultural, one may assume that danger to the scenery is not serious.

*Researches of Chester Stock and E. L. Furlong.* In the present field season it has been possible for Dr. Stock to make two visits to the region of earlier studies in eastern Oregon for work on problems of geology and paleontology of that area. These visits have covered both field work at localities of exceptional importance, where additional information has been needed, and conferences with other investigators concerned with sections of the John Day area. As result of these studies Dr. Stock has brought to the point of decision consideration of a number of critical questions relating to faunal zones, thus making possible conclusions which are being fitted into the program of interpretation of the geological sequence.

Dr. Stock has also given special attention to preparation of materials for a study of the history of life in this region, needed in connection with the plan for publication of a small book discussing the history of life and the appreciation of time as represented in the John Day section.

Mr. Furlong has continued his detailed study of structure, classification, and evolution of some of the most important mammal types of the John Day area.

*Researches of E. L. Packard.* Dr. Packard has assembled all the data and materials obtained in a long period of field and laboratory studies in preparation of a manuscript covering largely the sequence of form and evolution of the marine mollusks found in certain of the older formations of the John Day region. This series of studies gives a record of the life of the region from the earlier periods, represented largely by marine forms; these are followed by periods in which the fossil remains are largely those of land animals.

Dr. Packard has been effectively assisted by F. M. Anderson, of the California Academy of Science, who has placed his collections and the information available to him at Dr. Packard's service. At the same time the contribution of Dr. Packard in this cooperative work will undoubtedly help materially in certain of the studies which Dr. Anderson has had under way.

An important phase of Dr. Packard's study has been represented by the conferences which he has held with Dr. Buwalda on sequence of formations and geological structure of the regions in which the marine invertebrate faunas have been found.

*Researches of R. W. Chaney.* Some of the important results of investigations of R. W. Chaney on the history of floras in the John Day region can best be stated by the following quotation from a report based on his studies:

"Recently completed studies of two Lower Pliocene floras from northern Oregon emphasize the regional differences in vegetation which were becoming conspicuous in western America during later Tertiary time. The Troutdale flora from the western slopes of the ancestral Cascade Range includes such typically coastal genera as *Sequoia* and *Chamaecyparis*, whereas the Dalles flora to the east is made up largely of box elder, redbud, and other plants whose living equivalents now occupy stream borders in semiarid regions. Differences between these floras are less pronounced than those between modern forests on opposite sides of the Cascades, suggesting a lower topographic barrier during early Pliocene time. This is in accord with geological evidence that these mountains have been largely raised to their present elevation since the beginning of the Pliocene.

"Even during the Miocene epoch there were marked local differences in the vege-

tation of Oregon. The Mascall flora of the John Day Basin has swamp cypress, black oak, and hickory as its most abundant members; the Blue Mountains flora, from deposits of essentially the same age fifty miles to the east, is made up largely of beech, alder, and an oak which resembles the living *Quercus myrsinaefolia* of China; in the Stinking Water Basin, fifty miles to the south, black oak and alder are common, together with chinquapin and a conifer, *Glyptostrobus*, which has survived only in eastern Asia. These differences are interpreted as an expression of topographic diversity with its resultant climatic effects. They become even more pronounced over considerable ranges in latitude, as might be expected upon a planet the climate of which is primarily controlled by the sun.

"With any detailed study of the Tertiary vegetation of the past, from locality to locality in a restricted area, or from zone to zone over the continent, the whole idea of cosmopolitan floras becomes untenable. Doubtless there have been times of relative submergence when broad seaways reduced the effects of latitude upon climate, and when low relief brought more uniform living conditions and vegetation. But during the Tertiary period in western America, and particularly in its later epochs, there is little evidence of such uniformity. Progressive emergence and mountain building have brought about topographic and climatic diversity which have resulted in a wide range of forest types in the existing flora. Comparisons of fossil floras for purposes of correlation, either locally or over greater distances, must take into consideration the fact that floras differing from one another in many respects may still be of the same age if they lived under diverse climatic conditions. Only a knowledge of the vegetation of a given age over a wide area, a knowledge based on large fossil collections, will make pos-

sible the accurate interpretation of differences as well as similarities in the study of Tertiary plants."

#### PRESERVATION AND INTERPRETATION OF OUTSTANDING SCIENTIFIC AND SCENIC FEATURES OF THE JOHN DAY REGION

Future scientific and inspirational values of the John Day region of eastern Oregon will in considerable measure be determined by the possibility of protecting and interpreting that area in such manner that visitors can understand and enjoy the things of really great importance shown there.

Nature has preserved for us in the John Day area a remarkable record of geological history, of life, and of evolution. The stages in geological development have been such as to protect the major elements and at the same time expose them to view. As a result there is opportunity here to know certain aspects of the record of the earth not shown so clearly elsewhere. It is important to note that the region is not merely one in which the features have been opened to view in such manner that they can be examined easily. It must be realized also that even to the discriminating eye of science the story of the John Day region is one of exceptional significance and interest. There are expressed here characteristics found in many regions of the world, and with these a number of unusual features representing advanced steps in our knowledge of the way in which the earth was built, and in which life developed or evolved.

At a recent meeting of the Advisory Board on Educational Problems of Oregon Parks attention was given to the problem of finding means for protecting and interpreting a considerable area of the John Day region. The committee approved a program looking toward realization of

the project through utilization of sections bordering the state highway between the junction of the north fork and the middle fork of the John Day River and the Mas-call Ranch above Picture Gorge on the middle fork. It was believed that the part of the region described is one of the most interesting natural areas of this country, and that the story which it tells in science, scenic values, and inspirational stimulus is one of the most important in America. It was considered that preservation of this region and interpretation of its values would be a service of the first order of importance, both in maintaining opportunity for important scientific work and in continuing the possibility for enjoyment of the scenic features.

Certain difficulties were recognized by reason of numerous and diverse ownerships of the land, but it was believed that cooperation among the agencies representing ownership would make possible the use of the most desirable features. It was thought that there might be such cooperation with owners of privately held lands that it would not be necessary to consider modification of activities on private ranches. It was suggested that, since the area follows a very fine Oregon highway, the region might be designated broadly as a parkway, with the state sponsoring the plan and with the State Parks Department perhaps serving as the administrative agency. Development of this idea is being carried forward as rapidly as possible, considering that with the relatively new point of view expressed, careful study must be given to means for realization of the project.

Attention is being given to preparation of a small book defining the features of the area which have special human interest, and giving such description as may make their value in the scientific, artistic, and human sense clear to visitors. It is

believed that such a book, if well written and illustrated, would stimulate interest and be an instrument of importance in guarding the region.

#### CONTINUED INTENSIVE RESEARCH ON THE RANCHO LA BREA LIFE SERIES

Although the conditions which have developed in the present emergency have limited certain aspects of the scientific program being carried on by many students in connection with the great fossil deposits at Rancho La Brea, it is important to note that significant progress has been made in the development of our knowledge of this remarkable record of life from the last geological period.

The program set up by the Museum of Los Angeles at Exposition Park for study of the fossil remains at Rancho La Brea has continued to go forward in such phases of the work as are looked upon as contributing ideas which have significance in our thought upon the meaning of history. Carrying out of the plan for an exhibit of materials on the site of their occurrence has been limited to some extent by reason of the need for application of materials in ways which are related to the defense program. But thought and planning as to how this exhibit may be organized to best advantage has not been interrupted completely, and we may assume that after this emergency a project of unusual significance will be developed by the Museum.

The principal guidebook relating to the occurrence and the collections from Rancho La Brea has been completely revised, and a fine new edition has been made available to the public.

Under the head of biological studies of the scientific materials obtained at Rancho La Brea, there has been advance in preparation of the monograph relating to the material concerning history of the camel

group in the period immediately preceding the present. These researches when completed will constitute one of the most significant contributions from the story of Rancho La Brea.

Life-size restorations have been made of some of the most important animals, such as the dire wolf (*Aenocyon dirus*) and the diminutive antelope (*Capromeryx minor*). These restorations, the work of Herman Beck and William Otto, have large value both on the scientific side and from the point of view of human interest.

One of the striking additions to our knowledge of the varied Rancho La Brea fauna is the group of fossil bird skeletons being restored by Eugene J. Fischer. To the group of mounted skeletons there has now been added one representing the large condor-like vulture (*Teratornis merriami*) and one of the extinct errant eagle (*Neogyps errans*). This collection furnishes for the first time an opportunity to visualize these important species in terms of size and bodily proportions.

Any reference to the Rancho La Brea fauna may properly include repetition of the statement that this collection of remains has important bearing upon the whole problem of history, as in considerable measure it crosses over the gap in time between the present and the period immediately preceding, in which the life world was in some respects similar to, and in other ways radically different from that of today.

#### EVOLUTION OF HIGHLY SPECIALIZED ANIMAL GROUPS CONTRIBUTING DATA OF EXCEPTIONAL INTEREST IN STUDIES ON EVOLUTION

Over a considerable period several groups of studies have been carried out for the specific purpose of obtaining data which would be of value in understanding

the manner of development or evolution of higher animals. Of these investigations, two have furnished material of special interest, one being an extensive series of researches by Remington Kellogg on history of the whale group, the other the relatively recent work of E. L. Furlong on evolution of the American antelopes.

Dr. Kellogg's study has had relatively high value in the whole field of biological studies, as we have an unusually satisfactory geological or historical record of the whale group of past ages. Being buried in the floor of the sea over a wide area of the earth's surface, and having a long evolutionary record over a considerable part of the world, the whales furnish exceptional material for studies on evolution. Also the whales have in the course of their history passed through a great number of stages, beginning with a type much like the modern carnivores of the wolf-cat group, passing through many stages including shore-dwelling carnivorous animals, and finally evolving into highly specialized animals limited entirely to life in the sea and illustrating very high specialization in aquatic life.

In the past year the work of Dr. Kellogg has been devoted in considerable part to study of the structure of the skull of embryonic whalebone whales. In adult whalebone whales the bones that comprise the brain case have been altered by slipping of one bone over another. In order to understand the development of this structure it has been important to make comparisons of the adult with the fetal skull; for there is reason to consider the possibilities presented by assumption that structure of earlier stages in history of this animal may be represented in the early embryonic stages of living forms. This comparison of the stages of development of the individual in a highly specialized animal with the stages of evolution as we

know them in the history of the group furnishes one of the most interesting bodies of fact for consideration in study of the general problem of evolution in the higher animals.

In the evolution and specialization of American antelopes, the most striking characteristics are restricted to a limited part of the skeleton. They seem, however, to show such a relation of the animal to its environment that the study may be seen to have value in researches on the meaning of evolution.

Investigations on the significance of variation and specialization in the American antelopes have been carried on through study of materials obtained in recent years by a group of researchers working upon the succession of geological formations in the middle and later Tertiary of north-western United States. Researches on the succession of antelope types found in these formations have been conducted for a considerable period by E. L. Furlong with the cooperation of Chester Stock and others. Added interest has been given to the work by reason of the fact that some of the steps in evolution of the American antelopes, leading up to appearance of the present-day pronghorn, resemble in a measure stages in evolution of the large and varied group of Old World antelopes within the same period.

In the past year Mr. Furlong has made considerable advance in study of these extinct antelopes, and with the use of abundant material he has been able to assemble portions of the skeleton which had previously been known only in part. The most interesting and important portions represent the skull, with the peculiar horn structures of this group.

With the cooperation of Chester Stock and the kind assistance of Childs Frick, it has been possible also to obtain the

assistance of William Otto in making what appear to be fully justified reconstructions of parts of the skull and skeleton, and especially the horn cores. The work of Mr. Otto, carried on with the fine touch of an artist and with precise understanding of anatomy and function of the parts of the skeleton involved, has made possible a contribution of the first order of interest. The reconstructions give a valuable picture of the history of the antelopes, and illustrate in a striking way the evolutionary stages of this group. As a result of the studies mentioned it has been possible to bring together a complete, though composite, skeleton of *Stoekoceros*. With the material available it has been possible also to model the musculature and prepare a plaster cast approximately of life size. The same procedure was carried out for the small antelope *Capromeryx*. In addition to these forms, a series of seven heads has been modeled representing the various American antelopes available. These have been cast in plaster to show on one side the bones of the skull and on the opposite side the restored musculature. This collection of reconstructions, together with the abundant and well preserved original materials, constitutes collectively a group of materials of exceptional value in study of a highly specialized group of Tertiary animals.

A study of the materials representing the genus *Stoekoceros* has been carried practically to completion in manuscript with illustrations. It is planned to bring this paper to publication in the near future.

Relation of the various stages in the history of these antelopes to the geological record has been worked out very carefully by Dr. Stock and Mr. Furlong, and further development of the geological and evolutionary story of the group is now being followed through field work.

## STUDIES ON THE HISTORY OF EARLY MAN

Researches on early stages of human history extending into the geological period preceding the present have been continued in the past year by several investigators associated with projects under way for a number of years. The present world crisis, extending to practically every country and affecting in one way or another nearly every type of activity, has limited the possibilities of these investigations, but has at the same time called attention to the importance of improving our understanding of the origin and development of all the races of the world. It has become clear that without a better understanding of the origin of peoples and of their relationships we shall not be able to obtain that interpretation of relations among nations so urgently needed. Without clear understanding of problems of nation and race it will not be possible to set up a plan of world organization through which continuing and profitable peace can be guaranteed.

It happens that some of the most destructive war activities in the past year have affected regions in which there were under way investigations on the earliest chapters of human history. Among the most significant were those in the region of the East Indies and adjacent continental areas. The work of G. H. R. von Koenigswald in the region of the East Indies was carried on close to the beginning of the war period, but information is not available as to the present situation with reference to materials secured. Fortunately a paper by Dr. von Koenigswald, entitled "The South African Man-Apes and Pithecanthropus," has been published recently through the Carnegie Institution of Washington, and included in it is a considerable quantity of data representing recent studies on the *Pithecanthropus* ma-

terial from Java. Since the work done by Dr. von Koenigswald in cooperation with a number of other leading investigators represents some of the most important studies on the beginnings of human history that have been undertaken anywhere in the world, it is to be hoped that further investigation may be developed on the basis of his researches as early as the world situation permits advance of studies in this field.

The researches of L. S. Cressman, of the University of Oregon, in the field of early man in northwest United States furnish an important contribution to our knowledge of human history in America. The results of these studies have been brought together recently by Dr. Cressman in a paper entitled "Archaeological researches in the northern Great Basin," now in process of publication by the Carnegie Institution of Washington. The paper is an excellent illustration of cooperative research in which specific fields have been examined by specialists and the reports integrated for final presentation. This study shows (1) the presence of early man in south central Oregon and a culture related to the Cochise culture, and (2) on the basis of the present evidence, a culture in this region antecedent to the Basket Maker and early Lovelock Cave. It either is in the direct line of development of the Basket Maker or represents a parallel development from a common ancestral stock.

Dr. Cressman's contribution represents not only an intensive study of a very important region in Oregon, but with this a wide comparison with other localities and researches in America. The method followed has not only covered a detailed consideration of individual artifacts and groups of artifacts, but has also presented correlation of data involving the various regions and lines of evolution followed in western North America. Through coop-

eration of the Guggenheim Foundation it was possible for Dr. Cressman to study in the various museums of the United States the archaeological collections bearing upon problems presented by the collections secured in Oregon. He also visited collections at Boulder through the courtesy of Earl H. Morris, and spent some time with Ernst Antevs in southern Arizona, examining sites of the Cochise culture.

Dr. Cressman has prepared an illustrated brochure on "Early man and Crater Lake" for the National Park Service, to be used for distribution to park visitors. This paper brings together the results of archaeological research and the very significant studies made recently principally by Howel Williams on geological history of the Crater Lake region. A paper on results of research in Oregon under the title "Cave and lake bed cultures of southcentral Oregon" was read at the annual meeting of the American Philosophical Society in Philadelphia in April 1942.

Dr. Cressman sees the development of this research program as including studies concerning the hypotheses of Oregon Basket Maker relationships. The crucial areas for continuation of these studies are (1) northern Nevada along the Humboldt River into Utah and south toward the Four Corners, and (2) north into Washington and along the Columbia. A possible third would be the Snake River. It is believed that systematic work should be carried on in these areas for at least ten years in order to secure the full story of prehistory in this part of the Northwest and its relation to the Southwest.

#### RESEARCH ON MAJOR PROBLEMS OF THE GRAND CANYON

During a period of ten years or more in which study was being devoted to interpretation of features of the Grand Canyon

region which should be of major interest to visitors, special attention was given by the committee on cooperation with the National Park Service to the definition and interpretation of principal problems in the story of the Canyon. At the time this work was being done, one of the most distinguished investigators in the group made comment to the effect that in all probability at least half of the major problems presented by the Grand Canyon were not as yet sufficiently well understood to make possible an intelligent interpretation for the benefit of the public.

In the years that have followed, careful investigation has been carried on with the purpose of obtaining an understanding of those aspects of the Canyon which were assumed to be of special importance in a program of interpretation. The largest part in the conduct of this work was done by Edwin D. McKee, formerly of the naturalist staff of the Grand Canyon National Park.

As a result of his studies Mr. McKee has finished and published a considerable number of important contributions relating to the geology and other natural features of the Canyon. A part of this work has been done in cooperation with the Carnegie Institution, and publications by Mr. McKee have appeared in connection with the reports of the Institution. In the past year Mr. McKee has completed a very important work on the "Stratigraphy and ecology of the Grand Canyon Cambrian rocks," with which there has been presented a study on the fossils of the Cambrian prepared by Charles E. Resser, of the United States National Museum. These contributions together represent one of the most interesting pieces of research in the Grand Canyon within recent years. The material consists partly of detailed discussion of the formations and the life which they contain, and partly relates to



interpretation of certain major problems of the Canyon concerning which information has been furnished in earlier publications.

Among many significant features of marine sedimentation to be demonstrated by the detailed studies of Mr. McKee are those relating to the effects of transgression and regression by the sea. Information was obtained on the steplike manner of advance by the sea, on relative rates of transgression and regression, on the distinctive types of sediment accumulated under each of these conditions, and on the causes of the advances and retreats. Important data were obtained also on the interrelation between contemporaneous lithologic facies, on the repetition of the same sequence of facies during distinct periods but at varying points in space, and on variations in fauna with different lithologic facies of contemporaneous age.

Much of the detail and accuracy involved in the Cambrian studies of Grand Canyon has been made possible by the presence of excellent "key beds," including thin intraformational conglomerates, fossil horizons, and distinctive lithologic units that were traceable for many miles. With the aid of these it was possible to establish beyond reasonable doubt certain relations between lithogenetic units and planes of time.

The Paleozoic strata in the Grand Canyon are especially well adapted to the type of detailed study involving time and space that has just been completed for the Cambrian deposits. This is true both because of the excellent and continuous exposures over a wide area, and because the cross section through various formations is approximately at a right angle to the cordilleran geosyncline. Taking advantage of these natural opportunities and using comparable methods, the Coconino, Toroweap, and Kaibab formations were studied previously. Similar investigations of the

Temple Butte, Redwall, Supai, and Hermit are in various stages of development. This program, when finished, should bring out not only fundamental changes as related to time, but contrasts also in space as illustrated by transitions between and within different environments such as delta, dune, playa, and sea.

#### PRESERVATION AND INTERPRETATION OF EXCEPTIONAL NATURAL FEATURES

In connection with all field studies in past years on especially interesting features of geology and paleontology, attempt has been made to find ways for protecting these exceptional realities in nature for use in scientific work and inspirational influence. This principle is being expressed in the effort directed toward preservation of the large group of unusual natural features in the John Day area, described above. It has also been of influence in the movements to preserve and interpret important areas set aside for state parks in California and Oregon and for national parks throughout the country. Long experience with research, teaching, and conservation makes it clear that natural areas thus selected and interpreted have supreme value in advancing science of the future and for inspiration and enjoyment of the public.

Rapid advance of what we call the influence of civilization tends either to change completely or to modify markedly most of the natural areas that have attracted attention in the past. The movement to preserve what is needed for the future must therefore proceed at rapid pace in order to guarantee protection of the regions which are most important. In the effort to secure the safeguarding of such areas there has fortunately been extraordinarily fine cooperation among the groups of persons interested in the values of science, art, nature appreciation broadly,

and inspiration which may lead to lifting the level of intellectual and spiritual interest in the country.

It is now clear that the effort to preserve natural features must include the whole range of possibilities from protection of cliffs that may be destroyed for road metal, to forests and glades which, through use, may lose their original character.

#### CONTRIBUTION RELATING TO INFLUENCE OF NATURE IN HUMAN EXPERIENCE

Within the past year there has been brought to completion for publication a book entitled *Influence of nature in human experience*. The material considered in this volume represents studies extending over a period of more than twenty years, arising from results of fundamental research in many phases of science. The contribution of this publication represents in considerable part development of ideas concerning relation of science and of nature specifically to progress of human thought as discussed in reports of 1939-1940 and 1940-1941 under the head of philosophical and human problems growing out of research.

In this work the effort has been made to determine the extent to which our thought and life are influenced through principles suggested by conditions or activities of the natural world. Attention has been given to fundamental types of belief relating to conditions in nature as they are found in present-day philosophies or religions, and also to some that seem to have originated in past time through intensive study of features recognized in the expression of natural forces. The suggestion has been made that the reflection of what we see in nature appearing in our fundamental thinking indicates that we are in large measure affected by principles showing themselves in the world about us

through what we describe in science as natural law.

The attempt has been made also to point out the need for more careful study of basic principles arising out of natural law as they affect development of present-day peoples and their relations to one another. It is suggested that out of such a study relating to the fundamentals of human history it may be that we shall derive points of view of importance in the attempt to obtain a better understanding of world relations among existing peoples.

It seems, therefore, desirable, in the light of present-day knowledge, to inquire as to what influences of nature are of such type that they may be considered as affecting our thought and the evolution of our life. There is reason to believe that of concepts in science arising from study of nature, there are none that would be looked upon as having influenced our belief more deeply than the generalized principles concerning development or evolution, known to reach through vast ages in the story of the earth, and leading ultimately to development of human life and institutions.

As an outgrowth of the view of nature seen today through personal observation and through study of the ideas which organized science has produced, we are led to believe that this vision of life development affecting us so deeply tends to transmute itself ultimately into emphasis on what we call progress. It is also important to note that our thought is deeply influenced by what might be called the uniformity or universality of expression by laws or modes of procedure of nature in space and in time.

As result of this situation one notes that in studying the universe widely in space, and deeply in time, out of our developing experience there tends to grow an attitude toward life that gives perspective instead of

formless space, order in the place of aimless movement, confidence in the dependability of the universe and its laws, and faith that the world is so constructed as to maintain the trend of its development or evolution or progress.

Such an attitude toward this world and its meaning is enormously important to us when, as now, complicated dangers and evils seem almost to overwhelm us. This situation may be presented humanly by the statement that of conditions considered by us as exceptionally significant in shaping our lives, there would be almost universal appeal for guaranties of opportunity to make progress, and for the kind of security favorable for our advance. Such were the basic conditions for living defined in our Declaration of Independence. Life, liberty, and the pursuit of happiness are involved in opportunity and security. While realizing that the factors governing attainment of these situations may seem of temporary character, in general we are impressed by evidence indicating that the real controls are of long-time or permanent effect.

#### COOPERATION IN RESEARCH AMONG INSTITUTIONS OF AMERICAN COUNTRIES

For several years special attention has been given to the planning of cooperative activities in connection with researches involving projects in several of the American countries. Through the courtesy of Dr. Pedro C. Sánchez, Director of the Central Office of the Pan American Institute of Geography and History, in Mexico City, it has been possible to establish and develop cooperative relations involving a number of the countries, including Mexico and several Central American and South American nations. This relation has been set up with a view to obtaining the cooperation of investigators in different in-

stitutions and countries who are working upon widely distributed occurrences of materials or situations having close relationship. It has been shown that such studies make especially important contribution in advancing research, as this method brings cooperation of investigators with different points of view. Ultimately it gives a better understanding of the subject and develops favorable relations between countries which may not otherwise have close touch in science and research.

The investigations to which special attention has been given represent first of all fields of research comprised in the President Emeritus research program. The actual field work in recent paleontological investigations on the later faunas of southern North America has been carried out mainly by investigators from California Institute of Technology, and the results are now being prepared for publication. Students of similar problems in Mexico have cooperated in these researches. This program should bring into close relation investigators from a number of institutions in the United States and in Mexico, and will aid in determining where the most important materials can be obtained in such localities as will permit satisfactory identification of the geological horizons represented. It is believed that this method of cooperation will help very materially to increase the important data already available on the history or evolution of the higher animals in Central and South America.

The method which has been applied for paleontological work is also in effective use over a wide field of archaeological and anthropological research as carried forward by many institutions in Mexico and the countries of Central America. The cooperative work done by the various countries in these investigations, as for example that within the Republic of Mexico, has

resulted in very marked advance in knowledge of the history of interesting regions and in the contribution of important data bearing upon general historical problems.

Studies of various types in the field of geology, ranging from the succession and structure of geological formations to special problems of volcanism and seismology, have also been carried out on a cooperative basis, and give promise of extremely important results. The contributions being made have special value in that they not only represent the points of view of different institutions and individuals working in different countries, but also involve a synthesis of materials from closely or sometimes even distantly related subjects.

#### REVISION, REGROUPING, AND PUBLICATION OF MANUSCRIPTS ON SPECIAL SUBJECTS

In the course of the past year a large quantity of manuscript material representing articles or addresses written in recent years has been brought together in a separate office for special study. Although the materials in this collection of papers have been drawn upon to some extent for use in publication of larger papers, the greater part of it has not yet been put into print. As the problems represented are closely related to major types of research in recent years, it is important to review these articles with the idea of restating or regrouping the materials in such a way that they will make the best possible presentation of each problem. In some cases it is necessary to fit together parts of manuscripts that have been handled independently, with the idea of using the most important data in publication. In other instances, in which immediate publication

is not essential, manuscripts may be provided with explanatory notes which would be useful in any future study of these subjects. They may then be filed with the archive of correspondence and publications remaining in Washington.

#### ADDRESSES AND SPECIAL PAPERS

The following addresses have been delivered by Dr. Merriam:

"Importance of the historical record of Santa Barbara," Conservation Council of California, Santa Barbara, December 6, 1941.

"Cultural objectives and unity of American peoples," World Affairs Institute, Riverside, December 8, 1941.

"Biological and human implication of the coming of spring," Botanists of Southern California, California Institute of Technology, Pasadena, March 14, 1942.

"Geologic features as bases of major concepts in public education," Cordilleran Section, Geological Society of America, California Institute of Technology, Pasadena, April 17, 1942.

"Conservation of ideals," Garden Clubs of California, Pasadena, May 1, 1942.

"Nature and the religion of progress," Federation of Natural Sciences of Southern California, Los Angeles, May 7, 1942.

"Human values of the redwoods," message of the President to the Council of the Save-the-Redwoods League, San Francisco, August 20, 1942.

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JOHN S. BILLINGS	1902-13	DARIUS O. MILLS	1902-09
ROBERT S. BROOKINGS	1910-29	S. WEIR MITCHELL	1902-14
JOHN L. CADWALADER	1903-14	ANDREW J. MONTAGUE	1907-35
WILLIAM W. CAMPBELL	1929-38	WILLIAM W. MORROW	1902-29
JOHN J. CARTY	1916-32	WILLIAM CHURCH OSBORN	1927-34
WHITEFOORD R. COLE	1925-34	JAMES PARMELEE	1917-31
CLEVELAND H. DODGE	1903-23	WM. BARCLAY PARSONS	1907-32
WILLIAM E. DODGE	1902-03	STEWART PATON	1916-42
CHARLES P. FENNER	1914-24	GEORGE W. PEPPER	1914-19
SIMON FLEXNER	1910-14	HENRY S. PRITCHETT	1906-36
WILLIAM N. FREW	1902-15	ELIHU ROOT	1902-37
LYMAN J. GAGE	1902-12	JULIUS ROSENWALD	1929-31
CASS GILBERT	1924-34	MARTIN A. RYERSON	1908-28
FREDERICK H. GILLETT	1924-35	THEOBALD SMITH	1914-34
DANIEL C. GILMAN	1902-08	JOHN C. SPOONER	1902-07
JOHN HAY	1902-05	WILLIAM BENSON STOREY	1924-39
MYRON T. HERRICK	1915-29	WILLIAM H. TAFT	1906-15
ABRAM S. HEWITT	1902-03	WILLIAM S. THAYER	1929-32
HENRY L. HIGGINSON	1902-19	CHARLES D. WALCOTT	1902-27
ETHAN A. HITCHCOCK	1902-09	HENRY P. WALCOTT	1910-24
HENRY HITCHCOCK	1902-02	WILLIAM H. WELCH	1906-34
WILLIAM WIRT HOWE	1903-09	ANDREW D. WHITE	1902-03
CHARLES L. HUTCHINSON	1902-04	EDWARD D. WHITE	1902-03
SAMUEL P. LANGLEY	1904-06	HENRY WHITE	1913-27
CHARLES A. LINDBERGH	1934-39	GEORGE W. WICKERSHAM	1909-36
WILLIAM LINDSAY	1902-09	ROBERT S. WOODWARD	1905-24
HENRY CABOT LODGE	1914-24	CARROLL D. WRIGHT	1902-08
SETH LOW	1902-16		

Besides the names enumerated above, the following were ex-officio members of the Board of Trustees under the original charter, from the date of organization until April 28, 1904: the President of the United States, the President of the Senate, the Speaker of the House of Representatives, the Secretary of the Smithsonian Institution, the President of the National Academy of Sciences.

# STAFF OF INVESTIGATORS FOR THE YEAR 1943

## ASTRONOMY

### MOUNT WILSON OBSERVATORY

Organized in 1904; George E. Hale, Director 1904-1923, Honorary Director 1923-1936

WALTER S. ADAMS, <i>Director</i>	ROBERT B. KING
ALFRED H. JOY, <i>Secretary</i>	PAUL W. MERRILL
*ARTHUR S. KING, <i>Supt. Physical Laboratory</i>	RUDOLPH MINKOWSKI
*JOHN A. ANDERSON	SETH B. NICHOLSON
WALTER BAADE	EDISON PETTIT
HAROLD D. BABCOCK	ROBERT S. RICHARDSON
WILLIAM H. CHRISTIE	ROSCOE F. SANFORD
THEODORE DUNHAM, JR.	GUSTAF STRÖMBERG
JOSEPH HICKOX	ADRIAAN VAN MAANEN
EDISON HOGE	OLIN C. WILSON
EDWIN P. HUBBLE	RALPH E. WILSON
MILTON L. HUMASON	

## TERRESTRIAL SCIENCES

### GEOPHYSICAL LABORATORY

Organized in 1906, opened in 1907; Arthur L. Day, Director 1907-1936

LEASON H. ADAMS, <i>Director</i>	ELBURT F. OSBORN
JOHN S. BURLEW	CHARLES S. PIGGOT
JOSEPH L. ENGLAND	EUGENE POSNJAK
RALPH E. GIBSON	HOWARD S. ROBERTS
ROY W. GORANSON	JOHN F. SCHAIRER
JOSEPH W. GREIG	EARNEST S. SHEPHERD
EARL INGERSON	GEORGE TUNELL
FRANK C. KRACEK	WILLIAM D. URRY
ORVILLE H. LOEFFLER	FRED E. WRIGHT
HERBERT E. MERWIN	EMANUEL G. ZIES
GEORGE W. MOREY	

### DEPARTMENT OF TERRESTRIAL MAGNETISM

Organized in 1904; Louis A. Bauer, Director 1904-1929

JOHN A. FLEMING, <i>Director</i>	ROBERT C. MEYER (resigned)
OLIVER H. GISH, <i>Assistant Director</i>	WILFRED C. PARKINSON
PHILIP H. ABELSON	RICHARD B. ROBERTS
CASPER J. ARONSON	WILLIAM J. ROONEY
LLOYD V. BERKNER	WALTER E. SCOTT
SCOTT E. FORBUSH	STUART L. SEATON
GEORGE K. GREEN	KENNETH L. SHERMAN
LAWRENCE R. HAFSTAD	WILLIAM F. STEINER
NORMAN P. HEYDENBURG	OSCAR W. TORRESON
ELLIS A. JOHNSON	MERLE A. TUVE
HENRY F. JOHNSTON	ERNEST H. VESTINE
MARK W. JONES	GEORGE R. WAIT
PAUL G. LEDIG	HARRY W. WELLS
ALVIN G. McNISH	

\* Retired in 1943.



## BIOLOGICAL SCIENCES

### DIVISION OF PLANT BIOLOGY

Desert Laboratory, opened in 1903, became headquarters of Department of Botanical Research in 1905. Name changed to Laboratory for Plant Physiology in 1923; reorganized in 1928 as Division of Plant Biology, including Ecology.

HERMAN A. SPOEHR, *Chairman*  
JENS C. CLAUSEN  
GARRETT J. HARDIN  
WILLIAM M. HIESEY  
DAVID D. KECK  
WINSTON M. MANNING

EMMETT V. MARTIN  
HAROLD W. MILNER  
FORREST SHREVE  
JAMES H. C. SMITH  
HAROLD H. STRAIN

### DEPARTMENT OF EMBRYOLOGY

Organized in 1914; Franklin P. Mall, Director 1914-1917; George L. Streeter, Director 1918-1940

GEORGE W. CORNER, *Director*  
ROBERT K. BURNS, Jr.  
LOUIS B. FLEXNER

CHESTER H. HEUSER, *Curator of the  
Embryological Collection*  
MARGARET R. LEWIS  
SAMUEL R. M. REYNOLDS

### DEPARTMENT OF GENETICS

Station for Experimental Evolution, opened in 1904, combined with Eugenics Record Office in 1921 to form Department of Genetics. Charles B. Davenport, Director 1904-1934; Albert F. Blakeslee, Director 1935-1941.

MILISLAV DEMEREC, *Director*  
UGO FANO, *Research Associate*  
BERWIND P. KAUFMANN  
EDWIN C. MACDOWELL  
BARBARA MCCLINTOCK

JAMES S. POTTER  
OSCAR RIDDLE  
MORRIS STEGGERDA  
HARRY E. WARMKE

### NUTRITION LABORATORY

Organized in 1907, opened in 1908; Francis G. Benedict, Director 1907-1937

THORNE M. CARPENTER, *Director*  
V. COROPATCHINSKY

ROBERT C. LEE

## HISTORICAL RESEARCH

### DIVISION OF HISTORICAL RESEARCH

Department of Historical Research organized in 1903; Andrew C. McLaughlin, Director 1903-1905, J. Franklin Jameson, Director 1905-1928. In 1930 this Department was incorporated as the Section of United States History in a new Division of Historical Research.

ALFRED V. KIDDER, *Chairman*

#### *Section of Aboriginal American History*

SYLVANUS G. MORLEY  
EARL H. MORRIS  
HARRY E. D. POLLOCK  
TATIANA PROSKOURIAKOFF  
KARL RUPPERT  
ANNA O. SHEPARD  
EDWIN M. SHOOK  
A. LEDYARD SMITH  
ROBERT E. SMITH  
GUSTAV STRÖMSVIK  
SOL TAX  
J. ERIC S. THOMPSON  
ALFONSO VILLA R.

#### *Section of Post-Columbian American History*

ELEANOR B. ADAMS  
ROBERT S. CHAMBERLAIN  
RALPH L. ROYS  
FRANCE V. SCHOLLES  
LEO F. STOCK

#### *Section of the History of Science*

GEORGE SARTON  
ALEXANDER POGO

## RESEARCH ASSOCIATES

MARION E. BLAKE, Archaeology  
PAUL S. CONGER, Biology

NEWTON B. DRURY, Study of Primitive Areas  
\*FRANK A. PERRET, Geophysics

### RESEARCH ASSOCIATES ENGAGED IN POST-RETIREMENT STUDIES

ALBERT F. BLAKESLEE, Genetics  
FREDERICK H. SEARES, Astronomy

GEORGE L. STREETER, Embryology

### RESEARCH ASSOCIATES CONNECTED WITH OTHER INSTITUTIONS

ERNEST B. BABCOCK (University of California), Genetics  
EDWARD L. BOWLES (Massachusetts Institute of Technology), Physics  
JOSEPH C. BOYCE (Massachusetts Institute of Technology), Physics  
E. H. BRAMHALL (University of Alaska), Terrestrial Magnetism  
G. BREIT (University of Wisconsin), Physics  
DIRK BROUWER (Yale University), Astronomy  
JOHN P. BUWALDA (California Institute of Technology), Geology and Paleontology  
W. E. CASTLE (University of California), Biology  
RALPH W. CHANEY (University of California), Paleobotany  
A. H. COMPTON (University of Chicago), Physics  
TH. DOBZHANSKY (Columbia University), Genetics  
CHARLES ELTON (Oxford University), Climatology  
G. GAMOW (George Washington University), Physics  
FRANK T. GUCKER, JR. (Northwestern University), Chemistry  
ROSS GUNN (United States Naval Research Laboratory), Terrestrial Magnetism  
ARTHUR T. HERTIG (Boston Lying-in Hospital), Embryology  
VICTOR F. HESS (Fordham University), Physics  
A. HOLLAENDER (National Institute of Health), Genetics  
THOMAS H. JOHNSON (Bartol Research Foundation), Physics  
ELLIOTT P. JOSLIN (New England Deaconess Hospital), Nutrition  
REMINGTON KELLOGG (United States National Museum), Paleontology  
GEORGE B. KISTIAKOWSKI (Harvard University), Chemistry  
S. A. KORFF (Bartol Research Foundation), Physics  
E. A. LOWE (The Institute for Advanced Study), Paleography  
EDWIN D. MCKEE (United States National Park Service), Geology and Paleontology  
ROBERT A. MILLIKAN (California Institute of Technology), Physics  
S. A. MITCHELL (University of Virginia), Astronomy  
T. H. MORGAN (California Institute of Technology), Biology  
WALTER H. NEWHOUSE (Massachusetts Institute of Technology), Geophysics  
WILSON M. POWELL (University of California), Physics  
ROBERT REDFIELD (University of Chicago), Anthropology  
HENRY N. RUSSELL (Princeton University), Astronomy  
H. C. SHERMAN (Columbia University), Nutrition  
JOEL STEBBINS (University of Wisconsin), Astronomy  
CHESTER STOCK (California Institute of Technology), Paleontology  
JOHN T. TATE (University of Minnesota), Physics

\* Deceased.

## OFFICES OF ADMINISTRATION

### *Office of the President*

VANNEVAR BUSH, *President*  
WALTER M. GILBERT, *Executive Officer*  
SAMUEL CALLAWAY, *President's Secretary*

### *Office of Publications and Public Relations*

\*THEODORE H. DILLON, *Director*  
AILENE J. BAUER, *Assistant to the Director*  
DOROTHY R. SWIFT, *Editor*

### *Office of the Bursar*

EARLE B. BIESECKER, *Bursar*  
J. STANLEY LINGEBACH, *Assistant Bursar*

### *Investment Office (New York City)*

DEVEREUX JOSEPHS, *Investment Officer*  
PARKER MONROE, *Investment Officer*

\* On leave of absence.

## ORGANIZATION, PLAN, AND SCOPE

The Carnegie Institution of Washington was founded by Andrew Carnegie, January 28, 1902, when he gave to a board of trustees an endowment of registered bonds of the par value of ten million dollars. To this fund an addition of two million dollars was made by Mr. Carnegie on December 10, 1907, and a further addition of ten million dollars was made by him on January 19, 1911. Furthermore, the income of a reserve fund of about three million dollars, accumulated in accordance with the founder's specifications in 1911, is now available for general use and a sum of five million dollars has been paid by the Carnegie Corporation of New York as an increase to the Endowment Fund of the Institution, payments having been completed in 1931. The Institution was originally organized under the laws of the District of Columbia and incorporated as the *Carnegie Institution*, articles of incorporation having been executed on January 4, 1902. The Institution was reincorporated, however, by an act of the Congress of the United States, approved April 28, 1904, under the title of the *Carnegie Institution of Washington*. (See existing Articles of Incorporation on following pages.)

Organization under the new Articles of Incorporation was effected May 18, 1904, and the Institution was placed under the control of a board of twenty-four trustees, all of whom had been members of the original corporation. The trustees meet annually in December to consider the affairs of the Institution in general, the progress of work already undertaken, and the initiation of new projects, and to make the necessary appropriations for the ensuing year. During the intervals between the meetings of the trustees the affairs of the Institution are conducted by an Executive Committee chosen by and from the Board of Trustees and acting through the President of the Institution as chief executive officer.

The Articles of Incorporation of the Institution declare in general "that the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind."

The Institution is essentially an operating organization. It attempts to advance fundamental research in fields not normally covered by the activities of other agencies, and to concentrate its attention upon specific problems, with the idea of shifting attack from time to time to meet the more pressing needs of research as they develop with increase of knowledge. Some of these problems require the collaboration of several investigators, special equipment, and continuous effort. Many close relations exist among activities of the Institution, and a type of organization representing investigations in astronomy, in terrestrial sciences, in biological sciences, and in historical research has been effected. Conference groups on various subjects have played a part in bringing new vision and new methods to bear upon many problems. Constant efforts are made to facilitate interpretation and application of results of research activities of the Institution, and an Office of Publications and Public Relations provides means for appropriate publication.

## ARTICLES OF INCORPORATION

PUBLIC No. 260. An Act to incorporate the Carnegie Institution of Washington.

*Be it enacted by the Senate and House of Representatives of the United States of America in Congress assembled,* That the persons following being persons who are now trustees of the Carnegie Institution, namely, Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, Samuel P. Langley, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, Ethan A. Hitchcock, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, their associates and successors, duly chosen, are hereby incorporated and declared to be a body corporate by the name of the Carnegie Institution of Washington and by that name shall be known and have perpetual succession, with the powers, limitations, and restrictions herein contained.

SEC. 2. That the objects of the corporation shall be to encourage, in the broadest and most liberal manner, investigation, research, and discovery, and the application of knowledge to the improvement of mankind; and in particular—

(a) To conduct, endow, and assist investigation in any department of science, literature, or art, and to this end to cooperate with governments, universities, colleges, technical schools, learned societies, and individuals.

(b) To appoint committees of experts to direct special lines of research.

(c) To publish and distribute documents.

(d) To conduct lectures, hold meetings, and acquire and maintain a library.

(e) To purchase such property, real or personal, and construct such building or buildings as may be necessary to carry on the work of the corporation.

(f) In general, to do and perform all things necessary to promote the objects of the institution, with full power, however, to the trustees hereinafter appointed and their successors from time to time to modify the conditions and regulations under which the work shall be carried on, so as to secure the application of the funds in the manner best adapted to the conditions of the time, provided that the objects of the corporation shall at all times be among the foregoing or kindred thereto.

SEC. 3. That the direction and management of the affairs of the corporation and the control and disposal of its property and funds shall be vested in a board of trustees, twenty-two in number, to be composed of the following individuals: Alexander Agassiz, John S. Billings, John L. Cadwalader, Cleveland H. Dodge, William N. Frew, Lyman J. Gage, Daniel C. Gilman, John Hay, Henry L. Higginson, William Wirt Howe, Charles L. Hutchinson, *Samuel P. Langley*, William Lindsay, Seth Low, Wayne MacVeagh, Darius O. Mills, S. Weir Mitchell, William W. Morrow, *Ethan A. Hitchcock*, Elihu Root, John C. Spooner, Andrew D. White, Charles D. Walcott, Carroll D. Wright, who shall constitute the first board of trustees. The board of trustees shall have power from time to time to increase its membership

## ARTICLES OF INCORPORATION

to not more than twenty-seven members. Vacancies occasioned by death, resignation, or otherwise shall be filled by the remaining trustees in such manner as the by-laws shall prescribe; and the persons so elected shall thereupon become trustees and also members of the said corporation. The principal place of business of the said corporation shall be the city of Washington, in the District of Columbia.

SEC. 4. That such board of trustees shall be entitled to take, hold, and administer the securities, funds, and property so transferred by said Andrew Carnegie to the trustees of the Carnegie Institution and such other funds or property as may at any time be given, devised, or bequeathed to them, or to such corporation, for the purposes of the trust; and with full power from time to time to adopt a common seal, to appoint such officers, members of the board of trustees or otherwise, and such employees as may be deemed necessary in carrying on the business of the corporation, at such salaries or with such remuneration as they may deem proper; and with full power to adopt by-laws from time to time and such rules or regulations as may be necessary to secure the safe and convenient transaction of the business of the corporation; and with full power and discretion to deal with and expend the income of the corporation in such manner as in their judgment will best promote the objects herein set forth and in general to have and use all powers and authority necessary to promote such objects and carry out the purposes of the donor. The said trustees shall have further power from time to time to hold as investments the securities hereinafter referred to so transferred by Andrew Carnegie, and any property which has been or may be transferred to them or such corporation by Andrew Carnegie or by any other person, persons, or corporation, and to invest any sums or amounts from time to time in such securities and in such form and manner as are permitted to trustees or to charitable or literary corporations for investment, according to the laws of the States of New York, Pennsylvania, or Massachusetts, or in such securities as are authorized for investment by the said deed of trust so executed by Andrew Carnegie, or by any deed of gift or last will and testament to be hereafter made or executed.

SEC. 5. That the said corporation may take and hold any additional donations, grants, devises, or bequests which may be made in further support of the purposes of the said corporation, and may include in the expenses thereof the personal expenses which the trustees may incur in attending meetings or otherwise in carrying out the business of the trust, but the services of the trustees as such shall be gratuitous.

SEC. 6. That as soon as may be possible after the passage of this Act a meeting of the trustees hereinbefore named shall be called by Daniel C. Gilman, John S. Billings, Charles D. Walcott, S. Weir Mitchell, John Hay, Elihu Root, and Carroll D. Wright, or any four of them, at the city of Washington, in the District of Columbia, by notice served in person or by mail addressed to each trustee at his place of residence; and the said trustees, or a majority thereof, being assembled, shall organize and proceed to adopt by-laws, to elect officers and appoint committees, and generally to organize the said corporation; and said trustees herein named, on behalf of the corporation hereby incorporated, shall thereupon receive, take over, and enter into possession, custody, and management of all property, real or personal, of the corporation heretofore known as the Carnegie Institution, incorporated, as hereinbefore set forth under "An Act to establish a Code of Law for the District of Columbia,

## CARNEGIE INSTITUTION OF WASHINGTON

January fourth, nineteen hundred and two," and to all its rights, contracts, claims, and property of any kind or nature; and the several officers of such corporation, or any other person having charge of any of the securities, funds, real or personal, books, or property thereof, shall, on demand, deliver the same to the said trustees appointed by this Act or to the persons appointed by them to receive the same; and the trustees of the existing corporation and the trustees herein named shall and may take such other steps as shall be necessary to carry out the purposes of this Act.

SEC. 7. That the rights of the creditors of the said existing corporation known as the Carnegie Institution shall not in any manner be impaired by the passage of this Act, or the transfer of the property hereinbefore mentioned, nor shall any liability or obligation for the payment of any sums due or to become due, or any claim or demand, in any manner or for any cause existing against the said existing corporation, be released or impaired; but such corporation hereby incorporated is declared to succeed to the obligations and liabilities and to be held liable to pay and discharge all of the debts, liabilities, and contracts of the said corporation so existing to the same effect as if such new corporation had itself incurred the obligation or liability to pay such debt or damages, and no such action or proceeding before any court or tribunal shall be deemed to have abated or been discontinued by reason of the passage of this Act.

SEC. 8. That Congress may from time to time alter, repeal, or modify this Act of incorporation, but no contract or individual right made or acquired shall thereby be divested or impaired.

SEC. 9. That this Act shall take effect immediately.

*Approved, April 28, 1904.*

# BY-LAWS OF THE INSTITUTION

Adopted December 13, 1904. Amended December 13, 1910, December 13, 1912, December 10, 1937, December 15, 1939, December 13, 1940, and December 18, 1942

## ARTICLE I

### THE TRUSTEES

1. The Board of Trustees shall consist of twenty-four members, with power to increase its membership to not more than twenty-seven members. The Trustees shall hold office continuously and not for a stated term.
2. In case any Trustee shall fail to attend three successive annual meetings of the Board he shall thereupon cease to be a Trustee.
3. No Trustee shall receive any compensation for his services as such.
4. All vacancies in the Board of Trustees shall be filled by the Trustees by ballot. Sixty days prior to an annual or a special meeting of the Board, the President shall notify the Trustees by mail of the vacancies to be filled and each Trustee may submit nominations for such vacancies. A list of the persons so nominated, with the names of the proposers, shall be mailed to the Trustees thirty days before the meeting, and no other nominations shall be received at the meeting except with the unanimous consent of the Trustees present. Vacancies shall be filled from the persons thus nominated, but no person shall be declared elected unless he receives the votes of two-thirds of the Trustees present.

## ARTICLE II

### MEETINGS

1. The annual meeting of the Board of Trustees shall be held in the City of Washington, in the District of Columbia, on the first Friday following the second Thursday of December in each year unless the date and place of meeting are otherwise ordered by the Executive Committee.
2. Special meetings of the Board may be called by the Executive Committee by notice served personally upon, or mailed to the usual address of, each Trustee twenty days prior to the meeting.
3. Special meetings shall, moreover, be called in the same manner by the Chairman upon the written request of seven members of the Board.

## ARTICLE III

### OFFICERS OF THE BOARD

1. The officers of the Board shall be a Chairman of the Board, a Vice-Chairman, and a Secretary, who shall be elected by the Trustees, from the members of the Board, by ballot to serve for a term of three years. All vacancies shall be filled by the Board for the unexpired term; provided, however, that the Executive Committee shall have power to fill a vacancy in the office of Secretary to serve until the next meeting of the Board of Trustees.
2. The Chairman shall preside at all meetings and shall have the usual powers of a presiding officer.



## CARNEGIE INSTITUTION OF WASHINGTON

3. The Vice-Chairman, in the absence or disability of the Chairman, shall perform his duties.
4. The Secretary shall issue notices of meetings of the Board, record its transactions, and conduct that part of the correspondence relating to the Board and to his duties.

### ARTICLE IV

#### EXECUTIVE ADMINISTRATION

##### *The President*

1. There shall be a President who shall be elected by ballot by, and hold office during the pleasure of, the Board, who shall be the chief executive officer of the Institution. The President, subject to the control of the Board and the Executive Committee, shall have general charge of all matters of administration and supervision of all arrangements for research and other work undertaken by the Institution or with its funds. He shall devote his entire time to the affairs of the Institution. He shall prepare and submit to the Board of Trustees and to the Executive Committee plans and suggestions for the work of the Institution, shall conduct its general correspondence and the correspondence with applicants for grants and with the special advisers of the Committee, and shall present his recommendations in each case to the Executive Committee for decision. All proposals and requests for grants shall be referred to the President for consideration and report. He shall have power to remove and appoint subordinate employees and shall be *ex officio* a member of the Executive Committee.

2. He shall be the legal custodian of the seal and of all property of the Institution whose custody is not otherwise provided for. He shall sign and execute on behalf of the corporation all contracts and instruments necessary in authorized administrative and research matters and affix the corporate seal thereto when necessary, and may delegate the performance of such acts and other administrative duties in his absence to the Executive Officer. He may execute all other contracts, deeds, and instruments on behalf of the corporation and affix the seal thereto when expressly authorized by the Board of Trustees or Executive Committee. He may, within the limits of his own authorization, delegate to the Executive Officer authority to act as custodian of and affix the corporate seal. He shall be responsible for the expenditure and disbursement of all funds of the Institution in accordance with the directions of the Board and of the Executive Committee, and shall keep accurate accounts of all receipts and disbursements. He shall submit to the Board of Trustees at least one month before its annual meeting in December a written report of the operations and business of the Institution for the preceding fiscal year with his recommendations for work and appropriations for the succeeding fiscal year, which shall be forthwith transmitted to each member of the Board.

3. He shall attend all meetings of the Board of Trustees.

4. There shall be an officer designated Executive Officer who shall be appointed by and hold office at the pleasure of the President, subject to the approval of the Executive Committee. His duties shall be to assist and act for the President as the latter may duly authorize and direct.

## BY-LAWS OF THE INSTITUTION

5. The President shall retire from office at the end of the calendar year in which he becomes sixty-five years of age.

### ARTICLE V

#### COMMITTEES

1. There shall be the following standing Committees, *viz.* an Executive Committee, a Finance Committee, and an Auditing Committee.

2. The Executive Committee shall consist of the Chairman and Secretary of the Board of Trustees and the President of the Institution *ex officio* and, in addition, five trustees to be elected by the Board by ballot for a term of three years, who shall be eligible for re-election. Any member elected to fill a vacancy shall serve for the remainder of his predecessor's term: Provided, however, that of the Executive Committee first elected after the adoption of these by-laws two shall serve for one year, two shall serve for two years, and one shall serve for three years; and such Committee shall determine their respective terms by lot.

3. The Executive Committee shall, when the Board is not in session and has not given specific directions, have general control of the administration of the affairs of the corporation and general supervision of all arrangements for administration, research, and other matters undertaken or promoted by the Institution; shall appoint advisory committees for specific duties; shall determine all payments and salaries; and keep a written record of all transactions and expenditures and submit the same to the Board of Trustees at each meeting, and it shall also submit to the Board of Trustees a printed or typewritten report of each of its meetings, and at the annual meeting shall submit to the Board a report for publication. The Executive Committee shall have power to authorize the purchase, sale, exchange, or transfer of real estate.

4. The Executive Committee shall have general charge and control of all appropriations made by the Board.

5. The Finance Committee shall consist of five members to be elected by the Board of Trustees by ballot for a term of three years.

6. The Finance Committee shall have custody of the securities of the corporation and general charge of its investments and invested funds, and shall care for and dispose of the same subject to the directions of the Board of Trustees. It shall have power to authorize the purchase, sale, exchange, or transfer of securities and to delegate this power. It shall consider and recommend to the Board from time to time such measures as in its opinion will promote the financial interests of the Institution, and shall make a report at each meeting of the Board.

7. The Auditing Committee shall consist of three members to be elected by the Board of Trustees by ballot for a term of three years.

8. The Auditing Committee shall, before each annual meeting of the Board of Trustees, examine the accounts of business transacted under the Finance Committee and the Executive Committee. They may avail themselves at will of the services and examination of the Auditor appointed by the Board of Trustees. They shall report to the Board upon the collection of moneys to which the Institution is entitled, upon the investment and reinvestment of principal, upon the conformity of expen-

## CARNEGIE INSTITUTION OF WASHINGTON

ditures to appropriations, and upon the system of bookkeeping, the sufficiency of the accounts, and the safety and economy of the business methods and safeguards employed.

9. All vacancies occurring in the Executive Committee and the Finance Committee shall be filled by the Trustees at the next regular meeting. In case of vacancy in the Finance Committee or the Auditing Committee, upon request of the remaining members of such committee, the Executive Committee may fill such vacancy by appointment until the next meeting of the Board of Trustees.

10. The terms of all officers and of all members of committees shall continue until their successors are elected or appointed.

## ARTICLE VI

### FINANCIAL ADMINISTRATION

1. No expenditure shall be authorized or made except in pursuance of a previous appropriation by the Board of Trustees, or as provided in Article V, paragraph 6, hereof.

2. The fiscal year of the Institution shall commence on the first day of November in each year.

3. The Executive Committee, at least one month prior to the annual meeting in each year, shall cause the accounts of the Institution to be audited by a skilled accountant, to be appointed by the Board of Trustees, and shall submit to the annual meeting of the Board a full statement of the finances and work of the Institution and a detailed estimate of the expenditures of the succeeding year.

4. The Board of Trustees, at the annual meeting in each year, shall make general appropriations for the ensuing fiscal year; but nothing contained herein shall prevent the Board of Trustees from making special appropriations at any meeting.

5. The securities of the Institution and evidences of property, and funds invested and to be invested, shall be deposited in such safe depository or in the custody of such trust company and under such safeguards as the Trustees and Finance Committee shall designate; and the income available for expenditure of the Institution shall be deposited in such banks or depositories as may from time to time be designated by the Executive Committee.

6. Any trust company entrusted with the custody of securities by the Finance Committee may, by resolution of the Board of Trustees, be made Fiscal Agent of the Institution, upon an agreed compensation, for the transaction of the business coming within the authority of the Finance Committee.

## ARTICLE VII

### AMENDMENT OF BY-LAWS

1. These by-laws may be amended at any annual or special meeting of the Board of Trustees by a two-thirds vote of the members present, provided written notice of the proposed amendment shall have been served personally upon, or mailed to the usual address of, each member of the Board twenty days prior to the meeting.

## ABSTRACT OF MINUTES OF THE FORTY-FIFTH MEETING OF THE BOARD OF TRUSTEES

The meeting was held in New York, N. Y., in the Board Room of the Carnegie Corporation of New York, on Tuesday, December 7, 1943. It was called to order at 11:00 A. M. by the Chairman, Mr. Forbes.

Upon roll call, the following Trustees responded: Thomas Barbour, James F. Bell, Robert Woods Bliss, Lindsay Bradford, Frederic A. Delano, Homer L. Ferguson, W. Cameron Forbes, Walter S. Gifford, Herbert Hoover, Frank B. Jewett, Roswell Miller, Henning W. Prentis, Jr., Elihu Root, Jr., Henry R. Shepley, Richard P. Strong, Charles P. Taft, James W. Wadsworth, Frederic C. Walcott, and Lewis H. Weed. The President of the Institution, Dr. Vannevar Bush, was also in attendance.

The minutes of the forty-fourth meeting were approved as printed and submitted to the members of the Board.

Reports of the President, the Executive Committee, the Auditor, the Finance Committee, the Auditing Committee, and of Chairmen of Divisions, Directors of Departments, and Research Associates of the Institution were presented and considered.

The following appropriations for the year 1944 were authorized:

Pension Fund .....	\$ 60,000
Administration (including expenses of Investment Office and of Insurance) .....	130,780
Publications (expenses of Office of Publications and Public Relations) .....	23,060
Departmental Research Operations .....	927,339
	<hr/>
	\$1,141,179

Dr. Jewett submitted his resignation as a member of the Finance Committee. This resignation was accepted with regret, and Mr. Prentis was duly elected to fill the existing vacancy, which terminates in 1944.

The meeting adjourned at 12:35 P. M., whereupon members journeyed to luncheon, upon invitation of Mrs. Carnegie, at her home.



## REPORT OF THE EXECUTIVE COMMITTEE

FOR THE YEAR ENDING OCTOBER 31, 1943

*To the Trustees of the Carnegie Institution of Washington:*

GENTLEMEN: Article V, section 3 of the By-Laws provides that the Executive Committee shall submit, at the annual meeting of the Board of Trustees, a report for publication; and Article VI, section 3 provides that the Executive Committee shall also submit, at the same time, a full statement of the finances and work of the Institution and a detailed estimate of the expenditures for the succeeding year. In accordance with these provisions, the Executive Committee herewith respectfully submits its report for the fiscal year ending October 31, 1943.

During this year the Executive Committee held six meetings, printed reports of which have been mailed to each Trustee and constitute a part of this report.

A statement of activities of the Institution is contained in the report of the President, which has been considered and approved by the Executive Committee, and is submitted herewith. Continued extension of use of resources and facilities of the Institution for war research by the government is a gratifying response to the offer by the Trustees of such services in the national interest. The Institution's contribution to the war effort provides a unique record of accomplishment within its own field of activity. The detailed estimate of expenditures for the succeeding year contained in the report of the President has been considered by the Executive Committee, which has approved the recommendations of the President in respect thereto and has provisionally approved the budget estimates based thereon and submitted therewith. Close attention has been given both by the Executive Committee and by the Finance Committee to the question of availability of funds for Institution activities in 1944, and budget recommendations are based upon the judgment of these Committees with respect to financial policy during the present national emergency.

The Board of Trustees, at its meeting of December 18, 1942, appointed Arthur Young and Company to audit the accounts of the Institution for the fiscal year ending October 31, 1943. The report of the Auditor, including a balance sheet showing assets and liabilities of the Institution on October 31, 1943, is submitted as a part of the report of the Executive Committee.

In addition to the report of the Auditor there is also submitted a financial statement for the fiscal year ending October 31, 1943, showing funds available for expenditures and amounts allotted by the Executive Committee, a customary statement of receipts and disbursements since the organization of the Institution on January 28, 1902, and a schedule of real estate and equipment at original cost. These statements together with the tables in the Auditor's report comprise a full statement of the finances of the Institution.

There are no vacancies in the membership of the Board of Trustees, of the Executive Committee, of the Finance Committee, or of the Auditing Committee.

W. CAMERON FORBES, *Chairman*

VANNEVAR BUSH

FREDERIC A. DELANO

WALTER S. GIFFORD

WALTER A. JESSUP

HENRY R. SHEPLEY

FREDERIC C. WALCOTT

LEWIS H. WEED

*November 1, 1943*

**FINANCIAL STATEMENT FOR FISCAL YEAR ENDING OCTOBER 31, 1943**

	Balances unallotted Oct. 31, 1942	Trustees' appropriations Dec. 18, 1942	Reversions and transfers Nov. 1, 1942 to Oct. 31, 1943	Total available 1943	Executive Committee allotments 1943	Transfers by Executive Committee	Unallotted balances Oct. 31, 1943
<b>Departmental Research Operations:</b>							
Embryology.....		\$77,540		\$77,540.00	\$77,540.00		
Genetics.....		118,350		118,350.00	118,350.00		
Nutrition Laboratory.....		18,700	\$1,500.00	20,200.00	20,200.00		
Geophysical Laboratory.....		144,272	4,000.00	148,272.00	148,272.00		
Historical Research.....		118,133	1,000.00	119,133.00	119,133.00		
Mount Wilson Observatory.....		200,275		200,275.00	200,275.00		
Plant Biology.....		60,690		60,690.00	60,690.00		
Terrestrial Magnetism.....		216,310	23,190.00	239,500.00	239,500.00		
Research Projects of Limited Tenure.....	\$3,595.07		4,920.98	8,516.05			\$8,516.05
Publication.....	65,898.30	22,380	12,512.64	100,790.94	78,373.77		22,417.17
Administration.....		130,580	13,500.00	144,080.00	144,080.00		
Pension Fund.....		60,000		60,000.00	60,000.00		
General Contingent Fund.....	163,145.56		165,465.35	328,610.91	6,000.00	\$214,595.00	108,015.91
Carnegie Corporation Emergency Fund.....	174,456.36		153,103.79	327,560.15	166,070.00		161,490.15
	<b>\$407,095.29</b>	<b>\$1,167,230</b>	<b>\$379,192.76</b>	<b>\$1,953,518.05</b>	<b>\$1,438,483.77</b>	<b>\$214,595.00</b>	<b>\$300,439.28</b>



# AGGREGATE CASH RECEIPTS AND DISBURSEMENTS FROM ORGANIZATION, JANUARY 28, 1902, TO OCTOBER 31, 1943

RECEIPTS		DISBURSEMENTS	
Securities Sold or Redeemed.....	\$85,404,950.43	Securities Purchased.....	\$94,943,993.95
Interest from Securities and Bank Balances.....	50,813,092.40	Accrued Interest on Securities Purchased.....	698,855.84
Sales of Publications.....	358,198.61	Pension Fund.....	1,394,191.94
Colburn Estate (Bequest).....	52,015.74	General Reserve Fund.....	30,477.43
Harriman Fund (Sale of Land).....	4,043.70	Insurance Fund.....	140,532.24
Teetle Estate (Bequest).....	5,160.62	Harriman Fund.....	117.76
Carnegie Corporation of New York (Endowment Increase and for Specific Purposes).....	8,499,381.24	Special Emergency Reserve Fund.....	63,819.41
From Other Organizations and Individuals for Specific Purposes.....	429,649.38	National Defense Revolving Fund.....	1,494,397.20
Pension Fund (Refunds).....	93,176.13	General Contingent Fund.....	279,457.15
General Reserve Fund (Refunds).....	251.18	Carnegie Corporation of New York Emergency Fund.....	55,288.64
Insurance Fund (Refunds).....	13,076.02	Administration Building and Addition:	
National Defense Revolving Fund (Refunds).....	1,457,136.31	Construction and Site (Old Building).....	309,915.69
Administration Building Addition Account, Rentals and Refunds.....	18,021.09	Construction (Addition to Administration Bldg.).....	416,206.07
Miscellaneous Refunds and Receipts.....	878,085.83	Site (Addition to Administration Building).....	68,570.96
		Miscellaneous Expenditures*.....	40,825.37
		Departmental Research Operations:	
		Departments of Research, Buildings and Equipment	3,894,784.71
		Departmental Operations.....	32,036,824.35
		Research Projects of Limited Tenure.....	5,441,517.15
		Publication.....	2,876,895.87
		Administration.....	2,750,994.31
		National Research Council.....	150,000.00
		Miscellaneous.....	9,008.82
		October 31, 1943, Cash in Banks.....	\$147,096,674.86
			929,563.82
			\$148,026,238.68

\* Includes Equipment \$7,206.41. Repairs and Alterations to Old Building \$18,599.29.

# REAL ESTATE AND EQUIPMENT, ORIGINAL COST

## Administration (October 31, 1943)

### Washington, D. C.

Building, site, and equipment.....		\$849,254.45
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## Division of Plant Biology (September 30, 1943)

### Stanford University, California (Headquarters)

Buildings and grounds.....	\$74,423.46	
Laboratory.....	39,799.05	
Library.....	25,862.02	
Operating equipment.....	13,901.82	153,986.35

## Department of Embryology (September 30, 1943)

### Wolfe and Madison Streets, Baltimore, Maryland

Library.....	\$4,228.96	
Laboratory.....	18,569.82	
Administration.....	7,754.37	30,553.15

## Department of Genetics (September 30, 1943)

### Cold Spring Harbor, Long Island, New York

Buildings, grounds, and field.....	\$289,989.35	
Operating equipment.....	33,600.13	
Laboratory apparatus.....	37,058.74	
Library.....	52,202.41	
Archives.....	45,488.90	458,339.53

## Geophysical Laboratory (September 30, 1943)

### 2801 Upton Street N.W., Washington, D. C.

Building, library, and operating appliances.....	\$291,353.68	
Laboratory apparatus.....	171,304.96	
Shop equipment.....	21,103.00	483,761.64

## Division of Historical Research (September 30, 1943)

### 10 Frisbie Place, Cambridge, Massachusetts

Operating equipment.....	\$32,233.08	
Library.....	13,685.60	45,918.68

## Nutrition Laboratory (September 30, 1943)

### 29 Blackfan Street, Boston, Massachusetts

Building, office, shop, and library.....	\$134,399.59	
Laboratory apparatus.....	32,611.21	167,010.80

## Mount Wilson Observatory (September 30, 1943)

### Pasadena, California

Buildings and grounds.....	\$222,458.33	
Shop equipment.....	47,562.91	
Instruments.....	684,986.05	
Furniture and operating appliances.....	148,222.48	
Hooker 100-inch reflector.....	638,519.81	1,741,749.58

## Department of Terrestrial Magnetism (September 30, 1943)

### 5241 Broad Branch Road N.W., Washington, D. C.

Building, site, and office.....	\$254,594.80	
Survey equipment.....	93,387.31	
Instruments, laboratory, and shop equipment.....	465,482.87	813,464.98

**\$4,744,039.16**

## REPORT OF AUDITORS

*To the Board of Trustees  
Carnegie Institution of Washington  
Washington, D. C.*

We have made an examination of the books and accounts of CARNEGIE INSTITUTION OF WASHINGTON for the year ended October 31, 1943.

Income from investments and other sources has been duly accounted for and all disbursements were evidenced by paid voucher checks and/or properly approved invoices. The cash and securities were verified by certificates received from depositories and custodians. As in past years, the detailed accounts of the Departments of Research in the field have been audited by the Bursar of the Institution, and we are of the opinion, as a result of reviewing the internal audit methods in force, that such internal audit is satisfactorily conducted.

The securities are stated at cost, amortized cost, or value at date acquired, this being the established custom of the Institution. In accordance with a recommendation made in February 1940 by the Institution's Finance Committee, all premiums on all obligations purchased subsequent to January 1, 1940 are being amortized on a straight-line basis to the date on which an obligation is first callable or payable at par. The amortization of the premiums applicable to the year ended October 31, 1943 amounted to \$19,702.85 and has been deducted from the cost of such obligations.

Real estate and equipment are stated at original cost and books on hand for sale at their sales prices. No provision has been made for depreciation of property owned by the Institution.

We inspected certified copies of the minutes of the meetings of the Board of Trustees and Executive Committee as authority for the appropriations and allotments made during the year.

In our opinion, on the basis of valuations stated above, the accompanying balance sheet, statement of receipts and disbursements, and detailed schedule of securities properly present the financial position of Carnegie Institution of Washington at October 31, 1943 and the transactions for the year ended that date.

ARTHUR YOUNG & COMPANY  
*Accountants and Auditors*

*New York, N. Y.  
November 24, 1943*

**BALANCE SHEET OCTOBER 31, 1943**

ASSETS		LIABILITIES	
<i>Investments</i>		<i>Endowment and Other Funds</i>	
<i>Securities</i>		<i>Capital Funds</i>	
Cash:	\$32,302,950.05	Endowment Fund.....	\$27,000,000.00
Awaiting investment.....	164,093.10	Colburn Fund.....	103,310.80
Reserved for current needs.....	42,376.25	Capital Reserve Fund.....	3,594,514.83
		Harriman Fund (\$179,628.05 included in Property Fund below).....	340,061.90
		Teagle Fund.....	5,160.62
			\$31,043,048.15
<i>Property Accounts</i>		<i>Special Funds</i>	
Real Estate and Equipment at original cost:		Pension Fund.....	259,774.43
Office of Administration.....	\$849,254.45	General Reserve Fund.....	906,596.82
Departments of Research.....	3,894,784.71	Current Funds Invested.....	300,000.00
		<i>Property Fund</i>	
		Income Invested.....	\$4,564,411.11
		Harriman Property (Gift).....	179,628.05
<i>General Fund</i>		<i>General Fund</i>	
Income account.....	\$723,094.47	Current Obligations:	
Petty cash and stamps.....	500.00	Departmental Research Operations.....	\$467,679.11
		Research Projects of Limited Tenure.....	52,731.48
		Publication.....	74,365.46
		Administration.....	52,095.31
		General Contingent Fund.....	115,631.38
		Carnegie Corporation Emergency Fund.....	191,844.39
		Excess of Advances received on U. S. Government Contracts over disbursements made thereon.....	93,947.35
		National Defense Revolving Fund (includes reimbursable expenditures of \$134,482.80 from U. S. Government carried in accounts receivable, per contra).....	300,000.00
			\$1,348,294.48
			1,413.14
		Unappropriated Fund.....	\$1,349,707.62
		Less: Current Funds Invested (see above).....	300,000.00
		Value of publications and invoices.....	171,572.15
		Publication paper in stock.....	1,105.28
			\$1,049,707.62
			171,572.15
			1,105.28
			\$1,049,707.62
			171,572.15
			1,105.28
			\$1,049,707.62
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			\$1,049,707.62
			171,572.15
			1,105.28
			\$1,049,707.62
			171,572.15
			1,105.28
			\$1,049,707.62
			171

# RECEIPTS AND DISBURSEMENTS, NOVEMBER 1, 1942 TO OCTOBER 31, 1943

RECEIPTS		DISBURSEMENTS	
Securities Redeemed or Sold.....	\$4,397,582.39	Securities Purchased.....	\$4,579,244.21
Interest and Dividends from Securities.....	1,244,082.19	Accrued Interest on Securities Purchased.....	5,721.89
Sales of Publications.....	4,346.67	Pension Fund.....	94,797.18
Refunds and Other Credits.....	90,537.72	General Reserve Fund.....	649.55
From Other Organizations and Individuals for Specific Purposes:		General Contingent Fund.....	6,687.15
Carnegie Corporation of New York.....	164,000.00	Carnegie Corporation Emergency Fund.....	9,730.00
California Institute of Technology.....	4,166.60	Harriman Fund.....	37.78
Rockefeller Foundation.....	1,800.00	Departmental Research Operations*.....	859,352.08
Pension Fund (Refunds).....	1,548.20	Research Projects of Limited Tenure.....	40,437.54
General Reserve Fund (Refunds).....	73.80	General Publications.....	28,826.79
National Defense Revolving Fund (Refunds).....	826,158.80	Office of Publications.....	19,381.93
		Administration.....	188,824.26
		National Defense Revolving Fund.....	713,724.48
	\$6,734,296.37		\$6,547,414.84
Cash in Banks, November 1, 1942.....	742,682.29	Cash in Banks, October 31, 1943:	
		Uninvested principal:	
		Awaiting investment.....	\$164,093.10
		Reserved for current needs.....	42,376.25
		Income Account.....	\$206,469.35
			723,094.47
	\$7,476,978.66		\$7,476,978.66

\* Includes specific terminating projects administered through departments.

# SCHEDULE OF SECURITIES

Aggregate par or nominal value	Description	Ma-turity	Cost, amortized cost, or value at date acquired
UNITED STATES GOVERNMENT BONDS			
\$300,000	U. S. Guar. Federal Farm Mtg. Corp. 3s. ....	1949-44	\$303,070.31*
120,000	U. S. Guar. Reconstruction Finance Corp. Notes, 1s. ....	1944	120,000.00
460,000	U. S. of America Treasury Notes 1 1/8s. ....	1946	461,621.18*
575,000	U. S. of America Treasury 2s. ....	1950-48	578,275.14*
304,000	U. S. of America Treasury 2s. ....	1951-49	304,000.00
312,000	U. S. of America Treasury 2s. ....	1951-49	312,000.00
200,000	U. S. of America Treasury 2s. ....	1952-50	200,000.00
800,000	U. S. of America Treasury 2 1/8s. ....	1953-52	800,000.00
1,239,000	U. S. of America Treasury 2 1/8s. ....	1954-52	1,244,804.57*
300,000	U. S. of America Treasury 2 1/8s. ....	1958-56	300,000.00
350,000	U. S. of America Treasury 2 1/8s. ....	1967-62	350,000.00
75,000	U. S. of America Treasury 2 1/8s. ....	1968-63	75,000.00
1,200,000	U. S. of America Treasury 2 1/8s. ....	1969-64	1,200,000.00
400,000	U. S. of America Treasury 2 1/8s. ....	1969-64	400,000.00
50,000	U. S. of America Savings Defense "G" 2 1/8s. ....	1953	50,000.00
50,000	U. S. of America Savings Defense "G" 2 1/8s. ....	1954	50,000.00
50,000	U. S. of America Savings Defense "G" 2 1/8s. ....	1954	50,000.00
100,000	U. S. of America Savings Defense "G" 2 1/8s. ....	1955	100,000.00
\$6,885,000	Total U. S. Government. ....		\$6,898,771.20
FOREIGN BONDS			
\$90,000	Canadian National Ry. Co. 4 1/8s Guar. ....	1951	\$90,292.74*
100,000	Canadian National Ry. Co. 4 1/8s Guar. ....	1957	112,000.00
100,000	Canadian National Ry. Co. 5s Guar. ....	1969	98,500.00
57,000	Canadian National Ry. Co. 5s Guar. ....	1969	62,138.88*
35,000	Canadian National Ry. Co. 5s Guar. ....	1970	38,002.04*
91,000	Canadian Pacific Ry. Co. Coll. Tr. 5s. ....	1954	90,835.11
100,000	Province of Alberta Deb. 4 1/8s. ....	1958	93,750.00
100,000	Province of Alberta Deb. 5s. ....	1950	101,150.00
150,000	Province of Manitoba Deb. 4 1/8s. ....	1958	142,886.77
100,000	Province of Nova Scotia Deb. 4 1/8s. ....	1952	100,312.50
250,000	Shawinigan Water and Power Co. 1st Mtg. & Coll. Tr. S. F. 4 1/8s. ....	1967	238,510.42
100,000	City of Toronto Cons. Loan Deb. 5s. ....	1949	96,164.59
\$1,273,000	Total Foreign. ....		\$1,264,543.05
PUBLIC UTILITY BONDS			
\$275,000	Arkansas Power & Light Co. 1st & Ref. Mtg. 5s. ....	1956	\$267,953.12
75,000	Blackstone Valley Gas & Electric Co. Mtg. & Coll. Tr. 4s. ....	1965	76,875.00
247,000	Columbus & Southern Ohio Electric Co. 1st Mtg. 3 1/8s. ....	1970	264,639.52*
23,900	Commonwealth Edison Co. Conv. Deb. 3 1/8s. ....	1958	23,910.75
83,000	Commonwealth Edison Co. 1st Mtg. 3 1/8s. ....	1968	85,712.87
50,000	Consolidated Edison Co. of N. Y. Deb. 3 1/8s. ....	1948	50,875.00
40,000	Consolidated Edison Co. of N. Y. Deb. 3 1/8s. ....	1958	40,730.00
100,000	Detroit Edison Co. Gen. & Ref. Mtg. 4s. ....	1965	103,500.00
200,000	Gulf States Util. Co. 1st Mtg. & Ref. 3 1/8s. ....	1969	213,500.00
25,000	Houston Lighting & Power Co. 1st Mtg. 3 1/8s. ....	1966	25,750.00
200,000	Illinois Power & Light Corp. 1st & Ref. Mtg. 5s. ....	1956	196,750.00
150,000	Louisiana Power & Light Co., 1st Mtg. 5s. ....	1957	154,900.00
87,500	Metropolitan Edison Co. 1st Mtg. 4 1/8s. ....	1968	95,786.25
100,000	Minnesota Power & Light Co. 1st & Ref. Mtg. 4 1/8s. ....	1978	92,156.25
50,000	Monongahela West Penn Pub. Serv. Co. 1st Mtg. 4 1/8s. ....	1960	52,000.00
97,000	Montana Power Co., 1st & Ref. Mtg. 3 3/8s. ....	1966	97,970.00
100,000	New Orleans Public Service Co. 1st & Ref. Mtg. 5s. ....	1955	99,200.00
65,000	New York & Westchester Lighting Co. Deb. 5s. ....	1954	67,052.50
50,000	Northern States Power Co., 1st & Ref. Mtg. 3 1/8s. ....	1967	47,500.00
100,000	Ohio Edison Co. 1st Mtg. 4s. ....	1967	100,266.25
100,000	Ohio Power Co. 1st Mtg. 3 1/8s. ....	1968	101,500.00
100,000	Ohio Public Service Co., 1st Mtg. 4s. ....	1962	102,625.00
200,000	Oklahoma Gas & Electric Co., 1st Mtg. 3 1/8s. ....	1966	205,000.00
97,000	Oklahoma Natural Gas Co., 1st Mtg. 3 1/8s. ....	1955	104,507.80
100,000	Pacific Gas & Electric Co., 1st & Ref. Mtg. 3 1/8s. ....	1961	102,500.00
100,000	Pacific Gas & Electric Co., 1st & Ref. Mtg. 4s. ....	1964	104,000.00
141,000	Public Service Co., of No. Ill., 1st Mtg. 3 1/8s. ....	1968	145,230.00
125,000	Puget Sound Power & Light Co., 1st Mtg. 4 1/8s. ....	1972	130,280.50*
300,000	Southern California Edison Co., Ltd. 1st & Ref. Mtg. 3s. ....	1965	313,362.80*
149,000	Southern Natural Gas Co., 1st Mtg. Pipe Line, S. F. 3 1/8s. ....	1956	152,771.25*
300,000	Texas Electric Service Co., 1st Mtg. 5s. ....	1960	292,700.00
195,500	Texas Power & Light Co., 1st & Ref. Mtg. 5s. ....	1956	200,528.02
120,000	Toledo Edison Co., 1st Mtg. 3 1/8s. ....	1968	121,800.00
263,000	Virginia Electric & Power Co., 1st & Ref. Mtg. 3 1/8s. ....	1968	272,205.00
225,000	Wisconsin Electric Power Co., 1st Mtg. 3 1/8s. ....	1968	232,875.00
\$4,633,900	Total Public Utility. ....		\$4,738,912.88

\*After deduction for amortisation of premiums on bonds purchased subsequent to January 1, 1940. Amortization is on a straight-line basis to the date on which bonds are first callable or payable at par.

**SCHEDULE OF SECURITIES—Continued**

Aggregate par or nominal value	Description	Ma- turity	Cost, amortized cost, or value at date acquired
<b>COMMUNICATION BONDS</b>			
\$280,000	American Telephone & Telegraph Co., Conv. Deb. 3s.....	1956	\$305,185.26*
51,000	American Telephone & Telegraph Co., Deb. 3½s.....	1961	51,510.00
314,000	American Telephone & Telegraph Co., Deb. 3½s.....	1966	326,706.75
25,000	Mountain States Telephone & Telegraph Co., Deb. 3½s.....	1968	25,500.00
52,000	New England Telephone & Telegraph Co., 1st Mtg. 5s.....	1952	51,748.00
75,000	Southern Bell Telephone & Telegraph Co., Deb. 3½s.....	1962	72,375.00
\$797,000	Total Communications.....		\$833,025.01
<b>RAILROAD EQUIPMENT TRUSTS</b>			
\$44,000	Illinois Central R. R. Co., 4½s.....	1944	\$42,155.21
82,000	Pennsylvania R. R. Co. 2½s Guar.....	1956	81,283.64
\$126,000	Total Railroad Equipment Trusts.....		\$123,438.85
<b>RAILROAD BONDS</b>			
\$50,000	Central Pacific Ry. Co., 1st Ref. Mtg. 4s Guar.....	1949	\$48,250.00
100,000	Chesapeake & Ohio Ry. Co., Gen. Mtg. 4½s.....	1992	99,464.29
75,000	Chicago & W. Indiana R. R. Co., Cons. 4s.....	1952	70,357.66
50,000	Great Northern Ry. Co., 1st & Ref. Mtg. 4½s Std.....	1961	50,113.59
100,000	Great Northern Ry. Co., Gen. Mtg. 5s.....	1973	104,385.84
150,000	Louisville & Nashville R. R. Co., 1st & Ref. Mtg. 4½s.....	2003	149,475.00
50,000	Oregon Short Line R. R. Co., Cons. 1st Mtg. 5s.....	1946	48,405.15
75,000	Pennsylvania R. R. Co., Gen. Mtg. 4½s.....	1965	75,918.75
100,000	Pennsylvania R. R. Co., Cons. Mtg. 4½s.....	1960	104,662.50
50,000	Pittsburgh, Cin. Chi. & St. L. R. R. Co., Gen. Mtg. 5s Guar.....	1975	51,898.98
100,000	Southern Rwy. Co., 1st Cons. Mtg. 5s.....	1994	103,580.34
69,000	Terminal R. R. Assn. of St. Louis S. F. Gen. Ref. Mtg. 4s.....	1953	62,695.29
100,000	Toledo & Ohio Central Ry. Co., Ref. & Imp. Mtg. 3½s Guar.....	1960	99,000.00
200,000	Union Pacific R. R. Co., 1st Mtg. R. R. & Land Grant 4s.....	1947	215,154.08*
2,084,000	Union R. R. Co., Deb. 6s Guar.....	1946	2,084,000.00
100,000	Virginian Ry. Co., 1st Lien & Ref. Mtg. 3½s.....	1966	102,250.00
100,000	West Shore R. R. Co., 1st Mtg. 4s Guar.....	2361	78,140.00
50,000	Western Maryland Ry. Co., 1st & Ref. Mtg. 5½s.....	1977	42,677.19
\$3,603,000	Total Railroad.....		\$3,590,428.66
<b>INDUSTRIAL AND MISCELLANEOUS BONDS</b>			
\$21,000	Allis-Chalmers Mfg. Co., Conv. S. F. Deb. 4s.....	1952	\$21,666.54
100,000	Atlantic Refining Co., Deb. 3s.....	1953	103,130.64*
150,000	Bethlehem Steel Corp. Conv. S. F. Deb. 3½s.....	1952	148,750.00
200,000	Empire Gas and Fuel Co., S. F. Deb. 3½s.....	1962	185,687.50
3,000	Phelps Dodge Corp. Conv. Deb. 3½s.....	1952	3,000.00
113,000	Railway Express Agency, Serial Notes 1½s-2½s.....	1943-48	113,000.00
98,000	Republic Steel Corp. Gen. Mtg. 4½s.....	1956	101,579.05*
95,500	Republic Steel Corp. Gen. Mtg. 4½s.....	1961	98,520.09*
54,000	Scovill Manufacturing Co., Deb. 3½s.....	1950	54,720.00*
400,000	Shell Union Oil Corp., Deb. 2½s.....	1954	384,176.25
295,000	Socony-Vacuum Oil Co., S. F. Deb. 2½s.....	1955	306,751.80*
75,000	Socony-Vacuum Oil Co., Deb. 3s.....	1964	78,000.00
150,000	Standard Oil Co. of Calif. Deb. 2½s.....	1966	153,437.50*
200,000	Standard Oil Co., of N. J. Deb. 2½s.....	1953	203,459.45*
230,000	Westinghouse Electric & Mfg. Co., Deb. 2½s.....	1951	232,874.99*
122,000	West Virginia Pulp & Paper Co., 1st Mtg. 3s.....	1954	120,780.00
\$2,306,500	Total Industrial and Miscellaneous.....		\$2,309,533.81
<b>MORTGAGES</b>			
\$100,000	Lawyers Mtg. Co., Guaranteed 1st Mtg. Ctfs. 4¼%, No. 29940T....	1940	\$96,400.41
80,000	Lawyers Title and Guaranty Co., Guar. Mtg. 5¼% Par. Ctfs. No. D 424421381.....	1935	79,686.80
90,000	N. Y. Title and Mtg. Co., Guaranteed 1st Mtg. Ctfs., 5¼%, No. N97..	1938	88,701.51
91,750	N. Y. Title and Mtg. Co., Guaranteed 1st Mtg. Ctfs., 4¼%, No. N86..	1948	90,745.92
\$361,750	Total Mortgages.....		\$355,534.64
\$19,986,150	BONDS AND MORTGAGES—Funds Invested.....		\$20,114,188.10

\*After deduction for amortization of premiums on bonds purchased subsequent to January 1, 1940. Amortization is on a straight-line basis to the date on which bonds are first callable or payable at par.

**SCHEDULE OF SECURITIES—Continued**

Number of shares	Description	Cost, amortised cost, or value at date acquired
<b>PREFERRED STOCKS</b>		
100	American Brake Shoe Co., 5¼% Cum. Pref.....	\$12,653.50
2,257	American Cyanamid Co., 5% Cum. Pref.....	25,280.87
1,500	Appalachian Electric Power Co., 4¼% Cum. Pref.....	159,000.00
1,500	Bethlehem Steel Corp. 7% Cum. Pref.....	183,637.50
500	Case (J. I.) Co., 7% Cum. Pref.....	62,225.00
600	Cleveland Electric Illuminating Co., \$4.50 Cum. Pref.....	68,112.25
1,000	Deere & Company, 7% Cum. Pref.....	28,812.50
1,125	E. I. duPont de Nemours & Co., \$4.50 Cum. Pref.....	116,125.00
1,500	General Motors Corp. \$5.00 Cum. Pref.....	187,937.50
225	Grant (W. T.) Co., 5% Cum. Pref.....	7,642.76
530	Johns-Manville Corp. 7% Cum. Pref.....	67,294.52
5,000	Kress (S. H.) Co., 6% Cum. Spl. Pref.....	58,269.00
1,000	New York State Electric & Gas Corp. 5.10% Cum. Pref.....	103,250.00
1,000	Northern States Power Co., \$5.00 Cum. Pref.....	103,000.00
350	Ohio Power Co., 4¼% Cum. Pref.....	59,925.00
350	Oklahoma Natural Gas Co., \$5.50 Cum. Conv. Prior Pref.....	62,142.51
600	Pacific Telephone and Telegraph Co., 6% Cum. Pref.....	93,495.75
600	Public Service Co. of Oklahoma 5% Cum. Pref.....	60,900.00
1,144	Sherwin-Williams Co., 5% Cum. Pref.....	126,088.12
1,000	Standard Oil Co. of Ohio 5% Cum. Pref.....	109,385.47
400	U. S. Rubber Co., 8% Non Cum. 1st Pref.....	46,527.50
3,100	U. S. Steel Corp., 7% Cum. Pref.....	443,407.57
25,781	Total Preferred Stocks.....	\$2,185,112.32
<b>COMMON STOCKS</b>		
1,800	Air Reduction Company.....	\$107,905.16
2,000	American Brake Shoe Co.....	87,580.95
2,000	American Can Company.....	178,587.43
3,300	American Cyanamid Co. "B".....	95,812.55
4,000	American Radiator & Standard Sanitary Corp.....	73,114.91
200	American Telephone & Telegraph Co.....	21,007.50
2,600	Caterpillar Tractor Co.....	175,811.00
3,000	Chase National Bank of N. Y.....	97,025.00
3,200	Chrysler Corporation.....	286,011.32
1,800	Commercial Credit Co.....	81,018.00
2,300	Commercial Investment Trust Corp.....	125,904.94
200	Commercial National Bank and Trust Co. of N. Y.....	36,380.00
3,900	Continental Can Co.....	160,404.55
500	Continental Illinois National Bank & Trust Co. of Chicago.....	44,425.00
2,408	Continental Insurance Co.....	87,913.30
6,000	Continental Oil Co. of Delaware.....	162,943.08
980	Dow Chemical Co.....	117,622.28
2,100	E. I. duPont de Nemours & Co.....	329,363.35
1,900	Eastman Kodak Co.....	302,933.75
100	First National Bank of N. Y.....	152,840.00
10,900	General Electric Co.....	426,469.09
3,600	General Foods Corporation.....	145,855.17
8,800	General Motors Corporation.....	451,720.90
2,500	Goodyear Tire & Rubber Co.....	94,083.83
4,900	Grant (W. T.) Co.....	161,259.93
600	Guaranty Trust Co. of N. Y.....	161,651.50
7,100	Gulf Oil Corp.....	284,515.31
1,600	Hartford Fire Insurance Co.....	134,734.68
4,300	Humble Oil & Refining Co.....	257,024.26
1,800	Insurance Company of North America.....	128,164.15
908	International Business Machines Corp.....	117,182.04
800	Johns-Manville Corp.....	76,687.15
5,000	Kresge (S. S.) Company.....	114,950.90
662.67	Lawyers Mortgage Corp. Voting Trust Ctf.....	
1,100	Liggett & Myers Tobacco Co. "B".....	110,625.00
3,000	Merck & Co. Inc.....	122,980.85
2,100	Monsanto Chemical Co.....	204,625.50
6,300	Montgomery Ward & Co.....	302,892.84
1,500	National Cash Register Co.....	36,402.86
1,260	National Fire Insurance Co. of Hartford.....	74,842.50
5,100	National Lead Co.....	108,585.50
2,200	Newberry (J. J.) Co.....	104,039.50
2,600	New Jersey Zinc Co.....	172,294.50
3,200	Owens-Illinois Glass Co.....	197,239.00
1,400	Parke, Davis & Co.....	51,675.46
2,900	Penney (J. C.) Co.....	264,135.69
1,600	Phillips Petroleum Co.....	79,309.79
1,200	Pittsburgh Plate Glass Co.....	131,399.75
2,300	Procter & Gamble Co.....	138,903.14
1,600	Scott Paper Co.....	65,750.98
3,700	Sears, Roebuck & Co.....	287,682.41
5,600	Sharp & Dohme, Inc.....	79,972.65

(Continued on following page)



**SCHEDULE OF SECURITIES—Continued**

Number of shares	Description	Cost, amortized cost, or value at date acquired
<b>COMMON STOCKS—Continued</b>		
1,500	Sherwin-Williams Co. ....	\$147,079.47
11,700	Socony-Vacuum Oil Co. ....	142,824.05
1,500	Squibb (E. R.) & Sons. ....	86,250.00
4,000	Standard Oil Co., of California. ....	127,044.00
6,200	Standard Oil Co. of Indiana. ....	181,751.70
4,000	Standard Oil Co. of New Jersey. ....	215,173.50
2,300	Texas Company. ....	96,825.98
3,100	Timken Roller Bearing Co. ....	148,831.25
3,800	Union Carbide & Carbon Corp. ....	321,683.50
2,400	United Fruit Company. ....	171,224.48
1,400	United States Gypsum Co. ....	132,882.32
3,300	Westinghouse Electric & Mfg. Co. ....	346,049.63
2,000	Woolworth (F. W.) Co. ....	73,770.85
<b>193,818.67</b>	<b>Total Common Stocks. ....</b>	<b>\$10,003,649.63</b>
<b>219,599.67</b>	<b>COMMON AND PREFERRED STOCKS—Funds Invested. ....</b>	<b>\$12,188,761.95</b>
	<b>AGGREGATE INVESTMENTS (BONDS AND STOCKS). ....</b>	<b>\$32,302,950.05</b>

**REPORT OF THE PRESIDENT**

**OF THE**

**CARNEGIE INSTITUTION OF WASHINGTON**

**FOR THE YEAR ENDING OCTOBER 31, 1943**



# REPORT OF THE PRESIDENT

## OF THE

### CARNEGIE INSTITUTION OF WASHINGTON

As provided in the By-Laws of the Institution, the President has the honor to report to the Board of Trustees on the condition of the Institution and on its programs of research.

The report for this year will be brief, for the efforts of the scientific staff are now so largely devoted to war research that regular programs have been severely curtailed. The total research effort of the Institution is increased; in fact, measured in rate of expenditure, it is over twice as large as in the years just prior to the war. Results of value are indeed being attained, but they are nearly all of a confidential nature, reported currently to the armed services, but not publicly. In due time many of these results will be reported in histories of the scientific aspects of the war, but some, and indeed the most interesting, will undoubtedly not be made generally known for many years.

The conditions under which this large volume of research for government is carried on remain substantially unaltered. The Institution donates the use of its regular facilities and the services of its scientific staff. It is reimbursed, under its contracts with the War and Navy departments, and with the Office of Scientific Research and Development, only for its added expenses incident to the programs. A total of 62 contracts, on 26 separate projects, have now been entered into, involving a total expenditure through the Institution of government funds aggregating \$2,500,000. Many of these contracts have been completed, with indication on the part of the government that the re-

sults are proving of direct service in the war effort.

The Institution has loaned the services of 40 members of its staff to engage in war work in other organizations, some of whom continue on our salary rolls while on leave of absence. Others derive their salaries from their temporary associations, and in such cases, by action of the Executive Committee, it is the general policy of the Institution to pay the difference between total government compensation and 80 per cent of the member's stated salary, and to pay premiums on annuity and collective insurance policies.

The Geophysical Laboratory is now completely devoted to a war program, for which the nature of its facilities and staff is specially fitted. The Department of Terrestrial Magnetism is similarly occupied, with very little of its regular program continuing. In this case also, the unique position and background of the department has now become decidedly useful in an important program which utilizes much of the talent normally present. Mount Wilson Observatory is not so fully converted to war research, but has several important programs under way which utilize the special knowledge of astronomers and physicists. The war effort continues to need more outstanding talent in the physical sciences than is available, and to utilize to a lesser extent men from the biological sciences. There are, however, war research programs in most departments, and all have loaned numerous staff members. In addition to direct effort in cooperation with govern-

ment on problems in agricultural, medical, botanical, and chemical fields, a number of researches are being pursued on Institution initiative and funds, which may later prove to have importance in connection with the prosecution of the war, or the post-war period. The Division of Historical Research has no war program of its own, although several members of its staff are on leave in various connections.

The administration building in Washington is full to overflowing. The Office of Scientific Research and Development makes its headquarters there, with the result that it is the focus of scientific research on weapons and on military medical problems.

Though it is not appropriate to spread before the Board of Trustees the details of the war research being carried on by the Institution, much of it is known to members of the Board by reason of their individual connections. Practically all members of the Board are active in some phase of the war effort, and the duties of several bring them into contact with scientific war research generally, and with the efforts of the Institution in particular. The Chairman of the Board has of course been consulted frequently in connection with the many problems of management which arise in relations with government; and the Vice-Chairman, even though burdened with many duties because of the war, has aided in solving several knotty problems. It is a pleasure to record that Mr. Delano, Secretary of the Board of Trustees, has now occupied an office in the administration building, where his generous counsel on the affairs of the Institution will be even more available than in the past. Dr. Jewett, as President of the National Academy of Sciences, comes into intimate contact with a wide range of war research, and, as a member of the National

Defense Research Committee, one branch of the Office of Scientific Research and Development, aids in formulating and guiding a large program of research on weapons, a part of which is carried on in Institution laboratories. The Committee on Medical Research, which forms the other main branch of the Office of Scientific Research and Development, depends for its professional advice upon the committees of the Division of Medical Sciences of the National Research Council. Dr. Weed is Chairman of this Division, and hence closely in touch with all medical research in the country, and in particular with the relatively small contribution which the Institution makes in this field. Colonel Strong, in his relations with the medical affairs of the War Department, also makes frequent contact with the broad program of medical research. Dr. Loomis is Chairman of one of the divisions of the National Defense Research Committee, and also a member of the important Scientific Advisory Council in the Navy Department. Lieut. Commander Miller and Lieut. Commander Morgan, through their official duties, see the results of certain parts of the Institution's programs of war research. Mr. Root has advised on many matters; notably, he has aided Dr. Richards, the Chairman of the Committee on Medical Research, in connection with the research on penicillin, which promises to be the outstanding medical product of the war. Senator Walcott, in addition to his work on conservation, is a consultant to a division of the National Defense Research Committee, of which Dr. Leason H. Adams is Chairman. Other members of the Board, in their varied activities in connection with the prosecution of the war, have had occasional contact with the war effort of the Institution.

## REPORT OF THE PRESIDENT, 1943

### FINANCES

The income of the Institution continues to decline, although the decrease since last year is not large. Estimated income for the present year will probably be realized, and in fact somewhat exceeded. Thus the deficit, which was anticipated in the current budget, will probably be small. The budget for the coming year again includes an estimated small deficit, to be charged against reserves.

In budgeting, the full salaries of members of the staff on leave have again been included. The reversion of these salaries at the end of the year, less any amount which may be transferred for unusual expenses in connection with war research contracts, will undoubtedly more than cover the estimated deficit. Yet it is logical to budget in this manner, for we need to know the position of the Institution as it will be when absent members return. Currently, on this basis, the income does not quite meet costs. This has come about, both because of decreased income from endowment, and also because certain costs of operation have inevitably risen.

The few and moderate increases of salary included in the current budget, necessary to maintain the over-all salary scale of the Institution on a substantially level basis as older men retire, were put into effect. Salary rate schedules, including these increases, were prepared in accordance with instructions from the Director of the Office of Economic Stabilization, and they have now been approved by the National War Labor Board and by the Bureau of Internal Revenue of the Treasury Department. In the budget for next year similar small increases, in accordance with this schedule, have been included.

Some problems have arisen by reason of the presence in our laboratories of temporary employees, working alongside our

regular staff. Though the salaries of these temporary workers have been established entirely in accordance with such rules as apply, and with the general policies and customs pertaining to such work, there is a difference in the compensation of the two groups. This is natural, and in fact equitable, since those on temporary duty have added personal costs, and lack the relative security of permanent positions. There are, however, certain individual instances which have warranted correction. In some of these, where men on our permanent staff have been carrying greatly increased burdens and responsibilities of a temporary nature, the problem has been met by added compensation, paid from a special fund, and on a definitely temporary basis.

Owing to the continuing absence of General Dillon, on leave from his post as Director of the Office of Publications, and also because of general conditions, the publication program of the Institution has been much curtailed. Such publication as still occurs requires small appropriations, as there is still a balance in the publication fund.

The program of field work of the Division of Historical Research is now suspended. Such members of the Division as are not on leave are engaged in working up the results of field work for publication. This does not, however, need to result in added publication costs at once.

The annual payment from Carnegie Corporation of New York continues to be utilized to carry research programs of a terminating nature. It had been planned to utilize the balance of the fund for improving relations with other research organizations by grants to research workers in fields adjacent to those of the Institution. Under present conditions there is

## CARNEGIE INSTITUTION OF WASHINGTON

little opportunity along such lines which is truly attractive, and hence there is an accumulating balance in this fund. Since, however, the grants from the Corporation are now on a terminating basis, this income should not be considered in connection with current budgeting of continuing operations.

The matter of taxes in the District of Columbia is now definitely settled, as the bill passed by Congress in this connection exempts the Institution by name.

The cyclotron, at the Department of Terrestrial Magnetism, has now been completed. It will at the present time be necessary to provide only minor funds to operate it. In spite of the scarcity of certain essential materials, it was completed, rather more slowly than had been anticipated, because of the recommendation of the Committee on Medical Research that it be placed in use in connection with certain medical research problems. Such use will be taken care of largely by government funds, for it will be related definitely to the war effort.

With all these points included, it has not been difficult, in preparing the budget

for next year, to keep the estimated deficit small. As we now proceed, during the present year and next year, our reserves will actually not be depleted, and they will in fact increase somewhat, since we are not making full salary payments to absent members of the staff. Should we return to peacetime conditions immediately, however, we should be spending slightly more than our income.

The Finance Committee has given much thought to the problem that this situation presents. The Institution will not soon be in actual distress, unless indeed some form of inflation follows the war, or the general income from endowments continues downward to a substantial extent. As matters now stand, the Institution would be able to carry on almost as usual, but it would not have that freedom which it has had in the past to seize upon research opportunities, and to lead the way in certain specific areas of scientific research, for that freedom is present only when income is substantially more than enough to care for the bare operations of regular departments.

### PROGRAMS AND RESEARCH RESULTS

The reports of Directors concerning normal research programs are brief, and there are few opportunities this year to emphasize particular research accomplishments for the especial attention of the Board of Trustees.

In Dr. Corner's report of the work of the Department of Embryology there is a statement on developmental horizons in human embryos which is especially useful in clarifying the historical development and present outlook of the research program of this department. Even under war conditions the collection and study of early human embryos has continued with suc-

cess. Publication of a systematic classification of embryonic stages, combined with a catalogue of important human embryos in the Department's collection, has been begun. Programs of study of the effect of sex-gland hormones on very early embryos of the opossum, and on the functional histology of the ovary, have been pushed forward during the year. A long and comprehensive investigation of the development of reflexes, postures, and behavior patterns in the infant rhesus monkey, aided by the Department, was brought to final publication.

Under the direction of Dr. Spoehr, the Division of Plant Biology has investigated in a preliminary way a number of subjects of potential importance in connection with the war effort or the post-war period, of such nature that opportunities might be overlooked except for the attention of an independent laboratory. Though none of these have as yet yielded results which are striking or of great practical moment, there are some which hold such promise as fully to warrant intense preliminary exploration, and possibly early and concentrated effort to bring them to definite fruition. Among these may be mentioned the breeding of new forage grasses of importance for food production, and the determination of the products formed by diatoms and other algae under various environmental conditions. Excellent progress has also been made in the normal programs of biochemical investigation and experimental taxonomy.

The Department of Genetics, under Dr. Demerec, has aided in the war effort in cooperation with the Department of Agriculture, the National Institute of Health, and the Long Island Biological Association, and by change of emphasis in some of its normal programs, although the opportunities for war service are not as large in the biological field as in some other types of scientific research. Dr. Riddle is rounding out some of his research in endocrinology, especially in regard to the action of the parathyroid glands. Dr. MacDowell is studying an interesting mutation in mice, which aids in interpreting certain processes of normal development. Dr. McClintock continues to learn more concerning broken chromosomes in maize, by highly ingenious methods. Dr. Demerec continues to find that artificially produced mutants in certain fungi throw light on the mechanism of mutation.

At Mount Wilson Observatory Dr. Adams and his staff still manage to continue some astronomical research. At a time of minimum solar activity especial interest attaches to the appearance of the first sunspots of the new cycle, and a few such spots have now been observed, some of them at the highest solar latitudes ever recorded. The remarkable reversal of sign of magnetic polarity characteristic of a new cycle has been fully confirmed. Advances in the efficiency of stellar spectrographs have led to notable discoveries regarding the structure of the expanding shells surrounding the novae of our galactic system, and have aided in the interpretation of these extraordinarily important objects. Of exceptional interest is the discovery of a shell around the nova in Auriga of 1891. The powerful spectrographs in use with the 100-inch telescope have opened new fields in the analysis of stellar spectra, and in the study of differential motions in stellar atmospheres and of the distribution and composition of the gaseous clouds of interstellar space.

The Department of Terrestrial Magnetism has almost entirely turned to war research, fortunately in such manner as to utilize to the full the services of a staff outstanding in certain fields of earth physics which now acquire a special significance. Most of this is of military nature, but there is still some which can be properly made known. Dr. Fleming has summarized this in his report, and has also presented the broader aspects of one phase of the work in the eleventh Arthur lecture under the auspices of the Smithsonian Institution.

So completely is the Geophysical Laboratory devoted to war research that its Director, Dr. Adams, can report little beyond the preparation of earlier work for publication. This is plainly the situation also



in the Nutrition Laboratory under Dr. Carpenter.

Dr. Kidder reports the field work of the Division of Historical Research suspended for the duration. Staff members who are not in government service will have opportunity in the meantime to prepare adequate reports of their work. The present Maya program of cooperative studies was begun in 1929 and it has been planned to follow the period of field studies with a general summing up and submission of a

definitive report by 1950. After the war it may be necessary to continue a number of limited field investigations, but the whole program of the Division is still definitely pointed toward the objective mentioned above. There is expectation, therefore, that the present archaeological and historical studies of the Maya will be brought to a conclusion as contemplated, and that there will then be opportunity for careful consideration with regard to inauguration of future programs.

#### POST-WAR PROBLEMS

It is not too early, certainly, to study the broad problem of the status of scientific research in this country after the war. In this, the Institution occupies a unique position. It is the only fully independent institution of national scope devoted to a wide range of fundamental scientific research. Its presence affects the whole pattern of research in the United States in a decidedly favorable manner. It has great opportunities for creative work.

When this war is over, and even a partial account of the influence of scientific and technical research upon its progress becomes generally known, there is no doubt that the American people will see the need for continuing sound scientific research in this country. Those who have been in a position to realize the position of science in modern war already see the continuing need clearly. Yet the emphasis, from this restricted viewpoint, may well be upon applied research, and upon the material aspects of science generally. The Institution has never devoted itself to applied science; it is for this reason that much time and effort have been required to adapt its research to war purposes, and that the adaptation is even now incomplete. Rather, it has wisely pursued especially those branches of science which might otherwise not receive the attention which

their importance warrants, and this has led to normal programs which are farther from application than the programs of almost any other organization in the country. They are not less important on that account, but their importance has to be weighed in the vague terms of the fundamental knowledge and understanding of the race, rather than in terms of their possible impact upon the daily life of the people. There is some danger certainly, after a demonstration on the present scale of the importance of applied science to the security of the country, that the people generally, in their post-war insistence upon a vigorous national scientific effort, may be decidedly practical in their approach.

Yet it is well to remember the long-demonstrated idealism of the American people. If there is a post-war tendency to insist upon the strictly applied, it will not be in accordance with the general pattern during the history of the country, and it may hence be expected to be temporary. One need only consider the history of American education, and particularly of the state universities, to recognize the general background which controls. The people of this country have, in general, insisted that many of these institutions be essentially independent, even when they

paid their costs directly in taxes. There have been many exceptions of course, but the general trend remains. This has extended to the handling of research of an advanced nature. Research, of any sort, in this country is a relatively recent growth. It has appeared in organizations of many types. But it is notable that some of the finest research in the country, and some of the most fundamental, has been carried on in state universities, which are directly dependent upon the public purse. The great body of the people are interested in matters of the spirit; they are interested in the extension of knowledge for its own sake. Their interpreters often miss the point; there is a tendency, for example, to believe that a scientific subject is worth writing about popularly only if its results in terms of more and cheaper gadgetry for daily use can be demonstrated to the reader. There is also a tendency at times for legislatures to consider that their constituencies understand science only when it promises to cure human ills or defeat the insects that attack crops. Yet, if this were truly the case, there would have been little truly great and fundamental science in this country, and that little would have appeared only in the private institutions. Actually this country has forged ahead until, in the years preceding the war, it was fully abreast of the world in most aspects of pure science, and in some aspects it had taken a definitely leading position. This occurred because of a very large effort, and because of the work of many scientists, located in all sorts of organizations: in commercial laboratories, in government laboratories, in universities both state and private, and in definitely scientific institutions. It came about because of the support of the American people for this sort of endeavor, expressed in a multitude of ways. In the long run there is no reason to fear that fundamental science will not prosper in this country.

It is important, however, from the standpoint of the Institution, to study the trends carefully; for the forms of organization and the nature of support may well alter in the years just ahead. It would be surprising if incomes from present endowments could carry as large a share of the burden in the immediate future as in the immediate past. It also does not seem probable that new and large independent endowments will be soon created to such an extent as to offer a solution.

The private universities would of course be in difficulty should endowment incomes decrease substantially. They have, however, valuable assets in the interest and support of their alumni bodies. The extent to which the alumni of American colleges rally to their support is extraordinary. Not only do alumni of means thus aid their own institutions, but families that are far from being affluent contribute generously and often. There is a tendency in some quarters to be cynical about this type of giving; but there has been a tendency in some quarters in the inter-war period to sniff at all simple and wholesome reactions of the American people. This is one of the finest. It stems from the days when the town meeting voted of its painful income to support the country school. It forms a great outlet for that altruistic urge which, however limited in vision it may at times appear, is nevertheless the encouraging mark of a prosperous and unspoiled country. While this spirit remains, our colleges may indeed have times of retrenchment from overexpansion, but they will not have to become entirely practical and conventional in order to survive, and they will continue to be one place where pure science will find the freedom which is essential for its creative work.

There is no doubt, also, that government will continue to support the many laboratories which today form part of its structure. They perform a much needed func-

tion. The maintenance of standards, the scientific control of materials affecting the public health, the development of detailed knowledge of the public domain, the control of injurious insects and blights, the prediction of weather, these and many other scientific tasks are best conducted centrally and under government auspices. Those who labor in these ways merit full support, and their labors are essential to our health and prosperity. At times they can also add to our fundamental scientific knowledge in notable ways. Yet their primary responsibilities are heavy and definite, and they cannot depart from them generally for that detached and often indefinite search for new and basic knowledge which is characteristic of pure science, and which is necessary if the body of our national scientific effort is to remain complete.

The rise of the great industrial research laboratories in this country has been striking. Equally striking, but not so apparent, is the tendency for these laboratories to accompany their applied research, directed at the immediate needs of the industry, by a backlog of more fundamental study, often as far removed from immediate utility as much of the research in universities. It is an excellent trend, and it will certainly continue, if industry in this country is reasonably successful and prosperous. Still, full progress in pure science would hardly occur in industrial laboratories unless the independent scientist set the pace, and there are whole fields of pure science into which industrial laboratories would not be expected to enter.

As the pattern of scientific research develops after the war, it will be fully clear that it will not be complete unless independent scientific institutions, among which the Carnegie Institution of Wash-

ington is notable, continue to conduct their share of the effort. It is not because their contribution, measured in dollars or man-years, is any considerable fraction of the total research effort of the country in all forms; indeed, the fraction today is very small. It is rather because there are things to be done, regions of thought to be explored, for which institutions of this sort are peculiarly adapted; and because their presence can have an integrating and inspiring effect upon research generally. If the trends should be such that no institution of this sort could function effectively, the loss to American science would indeed be serious.

There is no doubt that the Carnegie Institution of Washington will continue. There is some doubt whether it can maintain its affairs on a basis where it can not only conduct its own research programs, but also reach out with aid to others, and be in a position to initiate where there is need for the type of effort which it can alone supply. The problem of maintaining it in health through the vicissitudes of a post-war period is not yet even formulated to the point where it can be definitely grasped. At the proper time it must be solved. In the meantime the Institution is devoting its full effort to the winning of the war at the earliest possible moment. In this effort it is a partner with the great and powerful aggregate of American science in all its forms. It will undoubtedly continue to be a vigorous partner, when peace returns, in the task of bringing the true benefits of science to the people, to increase their safety and comfort, to remove their ills, and to add to their knowledge of their history and environment. Those who guide it have a serious obligation to ensure that it may thus contribute effectively and fully.

# REPORTS OF DEPARTMENTAL ACTIVITIES AND COOPERATIVE STUDIES

## ASTRONOMY

*Mount Wilson Observatory*  
*Special Projects*

## TERRESTRIAL SCIENCES

*Geophysical Laboratory*  
*Department of Terrestrial Magnetism*  
*Special Projects*

## BIOLOGICAL SCIENCES

*Division of Plant Biology*  
*Department of Embryology*  
*Department of Genetics*  
*Nutrition Laboratory*  
*Special Projects*

## HISTORICAL RESEARCH

*Division of Historical Research*  
*Special Projects*



# MOUNT WILSON OBSERVATORY

*Pasadena, California*

WALTER S. ADAMS, *Director*

As the war has increased in intensity, demands upon scientific men throughout the country have also increased and every institution has felt the need for contributing in all possible ways through its staff and its equipment to the success of the military forces. From the Observatory, additional members of the staff have gone to undertake research on problems relating to the war at various laboratories throughout the country; and of those who remain, several are giving a large proportion of their time to similar work with the facilities available in Pasadena. In addition, the instrument and optical shops are devoted almost exclusively to the design and construction of instruments for military use, under contracts with the Army

and the Office of Scientific Research and Development.

The reduction in the scientific staff has necessarily led to some decrease in the normal research activities of the Observatory and has thrown a heavier burden upon those who have continued their astronomical work. Although these consist for the most part of the older members of the staff, their interest and devotion have made it possible to continue the major investigations without interruption and have led to results of interest in every field. Often the continuity of research, especially of astronomical observation, adds very greatly to its permanent value.

## STAFF AND ORGANIZATION

### RESEARCH DIVISION

*Solar Physics:* Seth B. Nicholson, Harold D. Babcock, Joseph Hickox, Edison Hoge, Edison Pettit, Robert S. Richardson, Mary F. Coffeen, Elizabeth S. Mulders, Myrtle L. Richmond, Louise Ware.

*Stellar Motions and Statistics:* Adriaan van Maanen, Ralph E. Wilson, A. Louise Lowen.

*Stellar Photometry:* Walter Baade, Mary Joyner Seares.

*Stellar Spectroscopy:* Walter S. Adams, William H. Christie, Theodore Dunham, Jr., Milton L. Humason, Alfred H. Joy, Paul W. Merrill, Rudolph Minkowski, Roscoe F. Sanford, Gustaf Strömberg, Olin C. Wilson, Ralph E. Wilson, Dorothy N. Davis, Ada M. Brayton, Sylvia Burd, Cora G. Burwell, A. Louise Lowen.

*Nebular Photography, Photometry, and Spectroscopy:* Edwin P. Hubble, Walter Baade,

Milton L. Humason, Rudolph Minkowski, Sylvia Burd.

*Physical Laboratory:* Arthur S. King, John A. Anderson, Robert B. King.

*Editorial Division:* Paul W. Merrill, editor; Elizabeth Connor, librarian; Alice S. Beach, secretary and stenographer.

Alfred H. Joy has continued throughout the year as Secretary of the Observatory.

Of the members listed, Edwin P. Hubble, Theodore Dunham, Jr., William H. Christie, Olin C. Wilson, and Robert B. King are on leave of absence to engage in investigations relating to the war. In addition, Gustaf Strömberg and Dorothy N. Davis are devoting most of their time to war work in Pasadena. Many others have been engaged upon specific problems connected with the instruments for military use under construction in the optical and instrument shops.

Two members of the scientific staff who have been associated with the Observatory almost from its beginning retired during the year. Dr. Arthur S. King, Superintendent of the Physical Laboratory, retired on February 1, 1943, and Miss Louise Ware on August 1, 1942. The Observatory is deeply indebted to them for the many valuable contributions they have made to its success during the long period of their service.

#### RESEARCH ASSOCIATES

Sir James Jeans, Dorking, England; Henry Norris Russell, Princeton University; Frederick H. Seares, Pasadena; Joel Stebbins, University of Wisconsin.

Dr. Russell, during a visit to Pasadena in February and March 1943, continued his term analysis of the spectra of neutral and ionized gadolinium and succeeded in classifying many hundreds of lines according to energy levels. He also devoted considerable time to a study of the physical characteristics of the companions of very small mass recently discovered in a few stellar binary systems. Dr. Stebbins, assisted by Mr. William Boricius, of the University of Wisconsin, during the summer of 1942 measured about 150 stars of all spectral types with his photoelectric photometer. Dr. Seares, with the assistance of Miss Joyner, has completed and prepared for publication his extensive analysis of the colors, spectral types, and color temperatures of stars near the north pole, and has found interesting results for the structure and absorption of the obscuring clouds in this region.

#### TEMPORARY ASSOCIATES

Dr. S. A. Mitchell, Director of the Leander McCormick Observatory, and Dr. John C. Duncan, Director of the Whittin Observatory, both spent the summer months of 1942 in Pasadena and

carried on observations on Mount Wilson. Dr. Mitchell continued his investigation of the radial velocities of faint stars in a number of selected fields, and Dr. Duncan photographed several nebulae and star fields of special interest with the 100-inch telescope. Dr. Harold F. Weaver carried on photometric observations at the Observatory for about three months during the summer of 1942.

Many other scientists visited the observatory during the year, among them Colonel F. G. M. Stratton, of Cambridge University, and Dr. R. d'E. Atkinson, of the Royal Observatory at Greenwich. Dr. P. Swings, formerly of the Yerkes Observatory, is now in Pasadena engaged upon optical problems relating to the war, and his association with the scientific staff has been greatly appreciated.

#### INSTRUMENT CONSTRUCTION AND DESIGN

*Design:* Edgar C. Nichols, Harold S. Kinney.  
*Optical Shop:* John S. Dalton, Donald O. Hendrix.

*Instrument Shop:* Albert McIntire, foreman; Elmer Prall, instrument maker; Ernest W. Hartong, Myo C. Hurlbut, Fred Scherff, Oscar Swanson, Albert Labrow, Donald W. Yeager, machinists; James Chapman, pattern maker; Harry S. Fehr, cabinet maker.

On October 1, 1942, Mr. Dalton retired from active service in the optical shop. He had been with the Observatory for many years, during which he had taken a large part in the completion of the 60-inch and 100-inch mirrors and many other important optical units.

#### MAINTENANCE AND OPERATION

*Office:* Anne McConnell, bookkeeper; Dorothea Neuens, stenographer and telephone operator.

*Operation:* Ashel N. Beebe, superintendent of construction; Sidney A. Jones and Kenneth de Huff, engineers; Thomas A. Nel-

son, Floyd Day, Louis S. Graf, night assistants; Anthony Wausnock and Mrs. Wausnock, stewards; Arnold T. Ratzlaff, janitor.

Several of the individuals whose names are listed above have been associated with the Observatory for but part of the year.

## OBSERVING CONDITIONS

The winter season was characterized by abnormally heavy rainfall, three-fourths of which was concentrated in three storms in January, February, and early March. Within 24 hours ending at 4 P.M. on January 22, 1943, 14.85 inches of rain fell, and in the succeeding 24 hours an additional 13.40 inches. These precipitations are the heaviest for such periods on record at Mount Wilson. The total precipitation for the season was 65.85 inches, but the winter was unusually mild and the total snowfall was only 9.5 inches. Observing conditions, indicated in the accompanying record for the 60-inch telescope, were considerably above the average.

As a cooperative step toward the conservation of tires and fuel for motor cars, the buildings of the Observatory were closed to the public for the present period of rationing.

MONTH	OBSERVATIONS		
	All night	Part of night	None
1942:			
July.....	30	1	0
August.....	26	4	1
September.....	26	4	0
October.....	25	2	4
November.....	18	8	4
December.....	17	7	7
1943:			
January.....	12	4	15
February.....	13	8	7
March.....	12	5	14
April.....	13	7	10
May.....	16	11	4
June.....	23	2	5
Total.....	231	63	71
Mean 31 years.....	204	85	76

## SOLAR RESEARCH

### SOLAR PHOTOGRAPHY

Solar photographs were made on 327 days between July 1, 1942 and June 30, 1943 by Hickox, Hoge, Nicholson, Keith Pierce, and Richardson, as follows:

Direct photographs .....	654
<i>H<math>\alpha</math></i> spectroheliograms of spot groups, 60-foot focus .....	660
<i>H<math>\alpha</math></i> spectroheliograms, 18-foot focus...	1296
K $_2$ spectroheliograms, 7-foot focus...	9210
K $_2$ spectroheliograms, 18-foot focus...	1252
K prominences, 18-foot focus.....	1203

### SUNSPOT ACTIVITY

During the calendar year 1942, sunspot activity continued to decrease notably. Ob-

servations were made on 341 days, the largest number since daily magnetic observations of sunspots were begun, 26 years ago. Sixteen days were without spots in 1942, as compared with 2 in 1941. In 1942, 189 spot groups were observed, 63 less than in 1941, the northern and southern hemispheres being equally active.

The monthly means of the numbers of groups observed daily during the past two and one-half years are given in the first table on the following page.

The first sunspot group of the new cycle appeared on December 20, 1942 in latitude N 32°. It was very small, with irregular polarities. The second group appeared on



MONTH	DAILY NUMBER		
	1941	1942	1943
January.....	4.8	3.3	1.1
February.....	5.5	4.4	2.0
March.....	5.0	4.9	2.4
April.....	2.7	5.2	2.1
May.....	3.1	2.6	1.8
June.....	4.7	1.3	1.7
July.....	5.2	1.9	...
August.....	5.4	2.1	...
September.....	4.9	2.1	...
October.....	3.7	2.4	...
November.....	3.4	3.0	...
December.....	3.7	2.6	...
Yearly average.....	4.3	3.0	...

May 16, 1943 in latitude S  $41^\circ$ . It was the farthest south and the largest group ever photographed more than  $40^\circ$  from the equator. The third group, which was very small, appeared on June 7, 1943 in the region where the large group of May had been.

#### SUNSPOT POLARITIES

Magnetic polarities in each spot group have, so far as possible, been observed at least once. The classification of groups observed between July 1, 1942 and June 30, 1943 is indicated in the table given below. "Regular" groups of the old cycle in the northern hemisphere are those in which the preceding spot has N (north-seeking) polarity and the following spot S

polarity; in the southern hemisphere the polarities are reversed. For spot groups of the new cycle, the distribution of magnetic polarities is opposite to that just described for the old cycle.

#### SOLAR PROMINENCES

In continuation of his study of solar prominences, mainly with the monochromator, Pettit has given especial attention to the interactive and the tornado types. Photographs of an interactive prominence taken with the monochromator on August 7-8, 1942 showed clearly the interchange of gases, although a survey of the past spectroheliograph records of the Mount Wilson and Yerkes observatories had shown only unidirectional motion of the knots and streamers in similar objects. If electric fields form the motive force, the fact that knots and streamers can move from one prominence to another indicates that electric charges of either sign can exist within a prominence.

That interactive prominences may enter the eruptive state was demonstrated by the prominence of October 3, 1942, which showed velocities of 14, 21, and 42 km/sec, and moved along a trajectory inclined  $34^\circ$  to the solar radius. The angle of ejection of eruptive prominences, although usually small, is sometimes large,  $63^\circ$  in one case. Of the 39 available trajectories, two-thirds are inclined less than  $20^\circ$  to the radius.

Eruptive prominences move great dis-

HEMISPHERE	POLARITY					
	REGULAR		IRREGULAR		UNCLASSIFIED	
	Old cycle	New cycle	Old cycle	New cycle	Old cycle	New cycle
North.....	50	0	2	1	19	0
South.....	53	2	2	0	16	0
Whole sun.....	103	2	4	1	35	0

tances without change in velocity. Eighteen such motions which exceed 200,000 km have been observed, including two which exceed a solar radius.

A discussion of all the available data seems to indicate that the frequency of eruptive prominences is about 400 per year at sunspot maximum, and 25 to 50 per year at sunspot minimum. A study of the frequency with which eruptive prominences reach various heights shows that between 100,000 and 500,000 km the frequency is about the same, and that the chance that an eruptive prominence will exceed 500,000 km is only 0.2.

In previous observations of tornado prominences it was found by motion-picture projection that the peripheral velocity amounted to 54 km/sec in one case, but spectroscopic evidence was lacking. A prominence was finally observed spectroscopically on March 23, 1943 in which Doppler displacements of the *H $\alpha$*  line approximating  $\pm 1$  Å were indicated. This implies a peripheral velocity of about 45 km/sec. Higher velocities than this may be expected, since one tornado is known to have been destroyed by its centrifugal force.

A study of quiescent prominences under good atmospheric conditions shows that the best examples have a palisaded structure which might be compared to a forest of rodlike branches or withes. They are not necessarily connected with the chromosphere. At times 20 or 30 rods have been counted on the photographs. Each is about 2000 km wide and may be 50,000 km high. Other prominences never show this structure, although the dimensions of streamers in active prominences are of the same order. Measurements of a considerable number of streamers give widths which average 1000 km; widths of 500 km are common, of 4000 or 5000 km rare. Streamers may be several hundred thousand km

long, but those in ordinary active prominences are only about 50,000 km long.

#### THE H AND K LINES AND MAGNETIC STORMS

The comparison by Richardson of photographs of the H and K lines taken during the violent magnetic storms of September 18, 1941 and March 1, 1942 with similar photographs taken during a period of magnetic calm is still in progress. The object is to test the suggestion by Chapman that a cloud of charged particles moving earthward during a magnetic storm might be detected by a faint absorption line on the violet side of the solar lines. Difficulty has been experienced in finding a satisfactory method of reduction such that the intensities of the lines determined during periods of magnetic calm and magnetic storm are strictly comparable. This difficulty has been solved, and reduction of the tracings is now practically complete. A definite statement regarding the presence of faint violet absorption lines is impossible until a comparison and analysis of all the lines can be made in detail.

#### COMPOUNDS IN THE SUN

The occurrence of chemical compounds in spot and disk has been studied by Babcock and Mrs. Coffeen with the aid of vibrational analyses compiled by Pearse and Gaydon from laboratory data. Computations by Russell of molecular abundance have been extended to include (1) some additional molecules; (2) higher states of vibrational energy; (3) two states of electronic excitation for *NH*. This has led to the recognition of *O<sub>2</sub>* in the sun, where it appears in several faint extensions of the Schumann-Runge band system. *NH* is probably present in two low states of electronic excitation. Excitation potentials ranging up to about 4 volts are found rep-

resented in the spectra of the more abundant molecules, whereas for metallic oxides they are restricted to a few tenths of a volt.

Presence of  $O_2$  in the solar atmosphere, even in great dilution, must reduce greatly the outflow of radiation in the region  $\lambda 670$ – $\lambda 2000$  Å because of its enormous absorptive power.

Seventeen compounds, including two or three new ones, have been identified, but several claimed by other observers have been excluded.

#### ULTRAVIOLET SOLAR SPECTRUM

With a new combination of filters, Babcock has obtained several spectrograms which show many new lines between  $\lambda 2950$  and  $\lambda 3000$ . One plate shows 47 lines between  $\lambda 2975.5$  and  $\lambda 2983.6$ , where the best previous list, compiled by Buisson and Fabry, from a spectrogram taken with much lower dispersion, gives only 16 lines.

The spectra of a few large spots have been observed as far toward the ultraviolet as about  $\lambda 3050$ .

#### OTHER SOLAR INVESTIGATIONS

A series of photographs in the green region of the spectrum has been taken by Babcock with the Lummer plate and accessories for the measurement of the sun's general magnetic field, and additional photographs with the Lummer plate have been made at various points on the equatorial radius to determine the solar rotation. These spectrograms have not as yet been measured.

Babcock has used a special liquid filter to photograph a few sunspot groups at the 150-foot focus of the Solar Laboratory telescope at an effective wave length of about  $\lambda 3200$ . Good contrast was obtained, but the appearance of the spots was about the same as in green or yellow light.

Considerable time has been devoted by

Richardson to computations of tables of solar azimuths for use in experiments with sun compasses by the military forces.

#### ASTEROIDS, SATELLITES, AND COMETS

A search for the asteroid Adonis was made by Nicholson through photographic observations with the 100-inch telescope. No definite evidence of the presence of the asteroid was found on the photographs, although the area covered corresponded to a range of 14 days in the time of perihelion passage. Richardson assisted in the observations.

Nicholson has also reobserved the positions of the fainter satellites of Jupiter. With the assistance of Miss Richmond, the orbit of J IX has been recalculated and improved, and perturbations from 1938 to 1943 have been computed.

Periodic comet Wolf I was found by Baade close to the place predicted from Kamienski's ephemeris. Positions were obtained on five nights in November and December. The photographic magnitude was 18.6 on the international scale.

A series of photographs of Whipple's comet (1942f) obtained by Baade on March 11–12, 1943 with the 60-inch telescope revealed surprisingly rapid changes at the base of the tail, strong streamers rising from invisibility in less than three hours.

Several previously unidentified features in the spectra of comets in the visual and red regions have been found by Minkowski, in the course of a study of Whipple's comet, in which they are exceptionally strong, to be due to bands of  $NH_2$  appearing in ammonia-oxygen and nitrous oxide-hydrogen flames. Spectrograms in the blue region taken at heliocentric cometary distances of 2.1 A.U. showed as strong features only the (0,0) bands of CN at  $\lambda 3883$  and the  $\lambda 4050$  group of  $CH_2$ , with the CN bands stronger than those of  $CH_2$ .

## STELLAR INVESTIGATIONS

## PARALLAXES AND PROPER MOTIONS

In continuation of his program on stellar parallaxes, van Maanen has completed measurements of 14 faint stars of large proper motion.

Observations of proper motion by van Maanen have included a search for very faint stars of considerable motion made on photographs taken ten years or more apart. Second-epoch photographs of 14 additional Cepheid variables have been obtained, making a total of 91 fields of such stars now available for measurement. An interesting individual star under investigation was found by Dr. Zwicky to have a small color index, but seems to belong to the Taurus cluster and should be a white dwarf.

Two pairs of photographs of the  $\kappa$  Persei cluster taken at the 80-foot focus of the 60-inch telescope and separated by intervals of 27 and 17 years have been measured extensively by van Maanen. About 800 stars to photographic magnitude 16.1 have been included. Although the motion of the cluster with reference to the field stars is only about  $0''.004$ , the probable errors of measurement are so small that it has been possible to identify over 100 stars as field stars. If there were no space absorption, the total number to be expected should lie between 150 and 180. It is well known, however, that absorption amounting to one or even two magnitudes is present in this region, the effect of which would be to reduce the number of observable field stars. Probably all such stars to magnitude 15 are now known, but among the fainter stars the smaller proper motions and the larger probable errors of measurement make the separation of cluster from field stars increasingly difficult.

## FAINT COMPANION OF 61 CYGNI

Dr. Russell has investigated the physical characteristics of the companion of small mass in the system of 61 Cygni, the existence of which was inferred by Strand from systematic deviations in the orbits of the bright stars. The theories used by Russell, although successfully applied to normal lucid stars, require considerable extrapolation in the case of these small bodies, and the results are doubtless affected by large uncertainties. Nevertheless the conclusions are of much interest.

With the mass given by Strand, the minimum radius is found to be comparable with that of Saturn; the maximum radius, roughly 10 times that of the sun. Above two or three times the minimum radius, the gas laws will hold approximately and the mean internal temperature can be calculated. For a radius one-fourth that of the sun and a mean molecular weight of 1, the central temperature is found to be  $1,600,000^{\circ}$  K, but the surface temperature is below that of self-luminosity. As seen from the bright stars of the system, the companion shining by reflected light would be a planet much brighter than Saturn without its ring, but it is much too faint to be seen from the earth. The calculation indicates that the radiation of the companion could be maintained by contraction alone for a period of  $5 \times 10^9$  years at a cost of only  $1/400$  of its radius.

## PHOTOELECTRIC MEASURES OF STARS

Stebbins has continued the measures of colors of stars with a photometer devised and constructed by Whitford. The combination of a photoelectric cell with suitable filters isolates six spectral regions from  $\lambda 3500$  to  $\lambda 10000$ . The study of interstellar absorption from reddened B-type stars has been completed and is ready for publica-

tion. About 150 other stars of all types have been measured. The principal deviations from black-body radiation are caused by the strong hydrogen absorption in the ultraviolet region of A-type stars and by the strong bands in the red and infrared regions of M stars. Otherwise the stars are found to radiate much like black bodies. The color temperatures derived from these measures are not strikingly different from previous results, ranging from about  $24,000^{\circ}$  K for types O and early B down to  $2000^{\circ}$  K for the reddest M stars. The value for A0 is  $11,000^{\circ}$  K, and there seems to be no way of reconciling these measures with a higher temperature for this type.

#### RESULTS FROM COLORS AND SPECTRAL TYPES OF POLAR STARS

With the assistance of Miss Joyner, Seares has finished a series of investigations based on the colors and spectral types of stars near the north pole, which confirm and extend a number of provisional results summarized in earlier reports: The systematic errors in the color indices of the Mount Wilson *Polar Catalogue* affect only stars brighter than the ninth magnitude of types earlier than G0; the revised spectrum-color relation (international system, absorption-free) and the resulting color temperatures of stars remain unchanged; and the general uniformity of the obscuring cloud over the polar cap,  $20^{\circ}$  in diameter, now seems to be well established. The solar system is close to if not actually a little within the cloud. The color excess increases at a nearly linear rate to a value of 0.27 mag at about 450 parsecs, where the cloud apparently ends. The total absorption of photographic light by the cloud is therefore 70 per cent, of photovisual light 60 per cent ( $\lambda^{-1}$  law).

A subdivision of the polar cap into small fields shows everywhere much the same

result. Deviations from the mean absorption are appreciable but surprisingly small for so large a range in galactic latitude ( $18^{\circ}$ – $38^{\circ}$ ). The average deviation increases with the distance of the stars, but at most the root mean-square value is only 0.04 mag, or about one-seventh the color excess. Incidentally, this part of the discussion provides an exacting test of the constancy of the zero point of the color indices of the *Polar Catalogue*. For fields of 8 or 10 square degrees the local error is of the order of 0.01 mag.

A further result of considerable astrophysical interest is the generally small dispersion in color index for stars of the same spectral type, a matter on which hitherto we have had no reliable information. For types K0 and earlier the upper limit of the dispersion is 0.035 mag. For K5–M stars it is about 0.1 mag.

The deviations from the mean absorption and the dispersion in color are derived from series of residuals given by a certain equation of condition, and once determined can be used to find the principal remaining component of the residuals, namely, the accidental error of spectral classification. A good deal of information on the errors of various classification systems has thus been obtained.

#### EXTENSION OF THE PHOTOGRAPHIC SCALE IN CERTAIN SELECTED AREAS

Since a comparison of the final magnitudes mentioned in last year's report with those of the Mount Wilson *Catalogue* revealed marked divergences for two of the Selected Areas, an additional series of 15-minute exposures was obtained with the half-filter to check the brighter end of the earlier 60-minute series in all Areas investigated. The discussion of both sets of exposures, which cover the magnitude range 13.0 to 20.5, has been completed for S.A. 68. It shows that the magnitude scales of

the short and the long series are in excellent agreement, and that the discordances noted in the intercomparison with the Mount Wilson *Catalogue* must be ascribed to irregularities in the scale of the latter. As a check, Miss Joyner has measured the original plates for S.A. 68, all of which were of poor quality (the measures for the *Catalogue* were by other observers). Comparison of the revised magnitudes with the half-filter magnitudes shows that the waves of smaller amplitude have disappeared entirely and that those of larger amplitude are much reduced. Discordances of this type are not surprising, since the paucity of stars in high-latitude fields often makes it difficult to insure uniformity all along the scale. This difficulty does not affect the mean scale.

#### VISUAL LIGHT-CURVE OF NOVA PUPPIS (1942)

Nova Puppis was discovered independently by Pettit on the morning of November 10, 1942, and a series of measures with a Pickering wedge photometer was commenced which extended over 86 nights distributed throughout 6 months. The instrument was modified by replacing the parallel plate used to bring the artificial

star into the field with a pyroxalin film  $4\mu$  thick, thus doubling the brightness and eliminating the troublesome out-of-focus image.

The first measure was made on the ascending slope of the light-curve, and the maximum brightness observed,  $+0.35$  mag, was on November 11. The general form of the light-curve is that characteristic of rapidly changing novae, but no such large oscillations in light at time of transition from continuous to bright-line spectrum were observed as occurred in Nova Persei (1901) and Nova Aquilae (1918). The residuals from the mean curve are less than  $0.2$  mag, the probable error of the magnitude from a single night's observations being  $\pm 0.05$  mag. The last measures, on May 6, gave a magnitude of  $8.35$ , the light-curve having shown a uniform drop of  $1.04$  mag per 100 days.

The absolute magnitude of Nova Puppis at maximum of light as determined spectroscopically was  $-10.1$ . This would correspond to an energy radiation of  $5.3 \times 10^{44}$  ergs, about 50 per cent more than that of Nova Aquilae (1918). The Harvard photographs indicate that the pre-nova magnitude of the star must have been fainter than 17.

#### STELLAR SPECTROSCOPY

With advances in the study of stellar spectra, the number of stars found to exhibit variable spectral characteristics has increased very greatly. Stars which vary in light and those which show emission lines in their spectra are especially subject to spectral variation, and in many the changes are of great astrophysical interest. Since the variations are not necessarily periodic, the study of individual stars over a considerable time rather than groups of stars for brief periods is essential. As observational material accumulates, it becomes

possible to establish relationships between different stars and to divide them into groups according to spectral variations. At present, however, studies of individual stars form a considerable part of the stellar spectroscopic work in progress.

Interesting features of the year's work in this field have been the increasing application of the high dispersion of the Schmidt cameras of the coude grating spectrograph to the study of the finer detail and the structure of lines in the spectra of the brighter stars; and the extent to

which fainter stars have come within the reach of observation with moderate dispersion. The use of some of the extremely rapid plates recently made by the Eastman Kodak Company has enabled Joy to carry his observations of variable stars to magnitude 14 on an adequate scale; and the same emulsions have made it possible to photograph early-type stars of the sixth magnitude with the 114-inch camera of the coude spectrograph with an exposure time of 2 hours.

### TAURUS CLUSTER

Because their distances, and hence their absolute magnitudes, can be derived accurately from their motions, the stars of the Taurus cluster are especially useful for determining the relation between spectral type and luminosity among the stars in general. For this purpose it is essential that we know which stars are members of the cluster. Common proper motion is not necessarily decisive, owing to considerable stream motion in the general direction of the cluster vertex. Common radial velocity in addition to common proper motion should be fairly decisive. About 250 stars brighter than 11.0 have proper motions reasonably close to those of the brighter members of the cluster. Some years ago it was proposed to observe the radial velocities of as many as possible of these stars.

During the past year 142 spectrograms of 118 stars, with magnitudes 7.0 to 9.5, have been obtained by R. E. Wilson, who has measured all these and 69 earlier plates of 57 stars. All together, radial velocities are now available for 217 stars, although a considerable number depend upon but one plate. Of these, 150 are cluster members, 20 are probable, 25 doubtful, and 22 certainly not members. Thirty-five stars, mainly between magnitudes 9.0 and 11.0,

have not yet been observed, and about 80 need additional observations.

It is significant that practically all the ninth-magnitude A-type stars listed as members on the basis of common proper motion are definitely not members. The cluster stars, other than the few known giants, fall very closely upon the main type-luminosity sequence within the range A5 to K5. No member of class M has yet been found.

### EARLY-TYPE STARS WITH EMISSION LINES

*Supplement to Catalogue.* Ten years ago, Merrill and Miss Burwell published a *Catalogue and bibliography of stars of classes B and A whose spectra have bright hydrogen lines*. This compilation, which lists 416 stars and 363 references, has proved to be of considerable service to spectroscopic observers. The authors have now brought the *Catalogue* up to date by preparing a supplement with 250 stars and 407 references. Numerous notes record unpublished data and call attention to the chief features of some of the more interesting spectra. Of the 250 additional stars, 166 were discovered at Mount Wilson.

The tenth-magnitude star HD 242257, recently discovered to have bright lines in its spectrum, is of interest because the hydrogen lines have displaced dark components, a fact which indicates that hydrogen atoms are streaming outward from the star's surface with a velocity of 530 km/sec. Weak dark lines of neutral iron are undisplaced. The investigation of HD 142983 (48 Librae) has been continued by Merrill and Sanford. During the past year the radial velocity has decreased by about 20 km/sec.

*Combination spectra.* A series of spectrograms of the peculiar star BF Cygni, obtained in the fall of 1942, shows surprisingly rapid changes in the intensities of the nebular lines. A detailed study of

the displacements of various groups of bright lines is nearly complete. Other stars with combination spectra observed during the year are AX Persei, RW Hydrae, CI Cygni, and Z Andromedae.

#### DWARF STARS

Much time has been devoted by Joy to the completion of the program planned some years ago for determining the radial velocities, spectral types, and spectroscopic absolute magnitudes of a selected list of dwarf stars with large proper motions. It is expected that within a few months the observations of about 120 stars having proper motions greater than  $0''.35$  per year will have been completed. Emission lines of hydrogen and calcium have been found in the spectra of a number of these stars. The spectra of several very faint dwarf stars of especial interest have been observed by Humason.

#### VARIABLE STARS

Spectrographic observations of stars belonging to little-known classes such as RV Tauri, SS Cygni, R Coronae, W Virginis, and T Tauri variables have been continued by Joy. The spectrum of one of the components of the double variable star UZ Tauri showed a remarkable change in the autumn of 1942. As the star increased in brightness, the emission spectrum characteristic of the T Tauri stars appeared in such strength as to overshadow the dwarf Me spectrum previously seen. These observations indicate that the variation of light is probably of the T Tauri type and that a third star may be present in addition to the visual pair originally seen.

Observations of about 20 variable stars of high luminosity in the globular clusters have been continued.

A new investigation of the ultraviolet region,  $\lambda 3400$ – $\lambda 4000$ , of the spectra of long-

period variables has been begun by Merrill. This region, which is free from heavy bands, is of especial interest for the study of atomic lines.

#### N- AND R-TYPE STARS

Sanford has now determined the radial velocities of about 100 additional stars of types N and R, many of them from two or more spectrograms. Satisfactory agreement has been found between the results obtained with low dispersion and those for some of the brighter stars observed with the coude spectrograph. With the new Eastman IV N emulsion, spectra of three N-type stars were photographed in the region  $\lambda 7000$ – $\lambda 8700$ , one of them, 19 Piscium, with the 114-inch camera.

#### FAINT BLUE STARS

Spectroscopic observations of 48 stars found by Dr. Zwicky to have a very small color index have been completed by Humason. Fifteen of the stars are in the vicinity of the Hyades cluster, and the remaining 33 near the north galactic pole. Most of the stars are fainter than photographic magnitude 13.0 and have been observed with the low dispersion of 220 A/mm. The spectral types range from B0 to A, most of them being B0 to B5.

#### IDENTIFICATION OF ELEMENTS AND SYSTEMATIC DISPLACEMENTS OF LINES

Miss Davis has utilized many of the high-dispersion coude spectrograms of late-type stars for a study of the identifications and the displacements of certain lines, especially those of the rare earths. In the red region of  $\beta$  Pegasi the potassium lines are strong and displaced 2.5 km/sec to the violet in relation to the ordinary stellar lines. The rubidium pair is weak but present, and has a somewhat smaller displacement.



From measurements of the lines of numerous elements in the spectra of several giant stars of type M, Miss Davis draws the following conclusions: (1) Resonance lines of *Ca* II and *Al* I are displaced more than lines of other elements. (2) Displacements are small and to the violet for lines arising from levels with excitation potentials between 0.5 and 1.6 volts. (3) Absorption components of *Ti* resonance lines, when the lines are double, are less widely separated than those of *Fe*, *Cr*, and *Mn*. The mean position of the components of the double lines is found to be very close to the normal position, as previous results had already shown. A comparison of the spectrograms of  $\alpha$  Orionis by Adams gives definite evidence that the relative intensities of the components of the double lines are subject to considerable variation.

#### H AND K LINES IN LATE-TYPE STARS

The usual structure of the H and K lines in late-type giant stars consists of two emission components separated by strong central absorption with wide absorption wings on the outer sides of the emission lines. The emission components show wide differences in relative intensity and width from star to star, and appear to vary at different times even in the same star. In many respects the similarity of behavior to that in the solar spectrum is marked. An upper limit of 0.03 has been determined by Miss Davis for the ratio of energy in the emission components in  $\alpha$  Boötis to the total energy absorbed by the K line. The minimum equivalent width of the absorption is 21 Å. In the more luminous stars the central absorption line is displaced to the violet, but the mean of the wave lengths of the emission lines has the normal position.

There seems to be considerable evidence that the separation of the emission components is correlated with absolute mag-

nitude among the brighter stars, the separation increasing progressively with luminosity. As between dwarfs and giants the effect is very marked, having been noted qualitatively in earlier observations. A recent spectrogram of 61<sup>1</sup> Cygni taken by Adams with the 114-inch coude spectrograph shows H and K to have two emission components separated by only 0.17 Å. The corresponding separation in  $\alpha$  Orionis is 1.38 Å.

A by-product of this study by Miss Davis is that the *H $\epsilon$*  line in emission, first found by O. C. Wilson in the spectrum of  $\alpha$  Boötis, occurs in numerous stars of types G and K, but is not present in M-type spectra.

#### THREE BRIGHT EARLY-TYPE STARS

Sanford has continued his observations of the variable *H $\alpha$*  line in the spectrum of  $\beta$  Orionis. The emission may be on either side or both sides of the absorption line, may be completely absent, or may be so strong that the absorption is nearly masked. No periodicity has yet been found for these changes. Variations in the radial velocity of the star do not conform to Plaskett's velocity-curve.

Recent observations by Adams of the spectrum of P Cygni with high dispersion show the gradual disappearance of the greatly displaced violet absorption component of the hydrogen lines which was discovered a few years ago. This component, which was relatively sharp, gave a radial velocity of  $-240$  km/sec. It disappeared completely between July 1942 and April 1943. The remaining wide absorption showed many variations in structure.

Three coude spectrograms of  $\tau$  Scorpii, dispersion 2.9 Å/mm, provided the basis for a brief study by Merrill and Adams of the widths and displacements of lines of various elements. Total widths are approximately as follows: *H*, 23 Å; *He*, 1-8 Å;

*O*, *Ne*, etc., 0.5 Å. With a few exceptions, lines of various elements yield accordant values of the radial velocity. Some of the exceptions probably reflect the instability of the corresponding lines in the laboratory. The profiles and displacements of the helium lines offer strong evidence of Stark effect in the star's atmosphere.

### INTERSTELLAR LINES

Numerous stars of spectral type B in open clusters are under observation by Sanford both for correlation of the intensities of the interstellar H and K lines with the distances of the clusters and for a study of the broad interstellar absorption line near  $\lambda 4430$ . He has also added four stars of types N and R to the two previously known which show interstellar D lines separated from the stellar D lines.

The results of an investigation of the structure of the interstellar H and K lines in the spectra of 50 stars has been published by Adams. The spectrograms have the linear scale 2.9 Å/mm. More than 80 per cent of these stars show complex lines consisting of from two to five components, thus indicating the same number of discrete gaseous interstellar clouds between the observer and the stars. As a rule, stars in Perseus and Scorpius show the least complexity in these lines, and those in Orion, Sagittarius, and Cygnus the greatest. The intensities of the components have been estimated, and measurements of radial velocity provide a means for identifying clouds in neighboring parts of the sky.

Some clouds are found to extend over great areas. The narrowness of the components indicates the absence of any considerable turbulence in the clouds.

The additional sharp interstellar lines due to *Ca* I and *Fe* I and to the diatomic molecules *CN*, *CH* I, and *CH* II have also been studied on these spectrograms. Marked differences in relative intensity between the lines of *CH* I and *CH* II are found in different stars. Comparisons of radial velocity indicate which of the clouds producing the components of H and K are involved in the formation of these additional lines.

An examination of the brighter stars in the cluster of the Pleiades shows the presence of interstellar lines in eight of the nine stars investigated. They are probably masked by the strong absorption lines in the present spectrum of Pleione. Marked differences are found in the intensities of the lines in the various stars, and perhaps the most interesting result is that two stars, *Asterope* and *Merope*, show interstellar lines of ionized *CH* without interstellar H and K. These are the first stars to be found showing this peculiarity. Evidently the diversity in the physical conditions and perhaps in the composition of the clouds in the direction of the Pleiades cluster is very considerable.

An attempt was made by Adams to detect possible interstellar lines of the red *CN* band in the region  $\lambda 6500$ – $\lambda 9000$  of the star  $\zeta$  Ophiuchi. No such lines were found, but the interstellar lines of neutral potassium near  $\lambda 7700$  are well seen.

### GALACTIC NEBULAE AND NOVAE

A survey by Minkowski of 63 objects, photographed by W. C. Miller with an objective prism, which show *H $\alpha$*  in emission with little or no continuous spectrum, indicates that 32 are planetary nebulae and 7 are diffuse nebulae. The spectra of sev-

eral of these nebulae are of rare types. Most of the remaining objects are B- and O-type stars with strong emission lines, but some are stars of peculiar types. The most interesting of these is an irregular variable of a type closely related to *Z Andromedae*.

The spectrum shows numerous metallic emission lines and hydrogen absorption lines of most unusual structure. The absorption lines consist of several components of rapidly varying intensities with displacements between  $-500$  and  $-2200$  km/sec. These displacements are the largest yet observed, except in the spectra of some novae.

The spectrum of Nova T Coronae Borealis has undergone some rapid changes. A shell absorption spectrum in the ultra-violet region, which was observed by Minkowski in February 1943, disappeared one month later, and the spectrum is now similar to that observed before 1942.

The faint nebulosity in Cygnus has been reobserved spectroscopically by Humason with higher dispersion than that used previously.

Since important information can be gained from a study of the expanding shells around some of the nearer novae, both as to the luminosities of the novae and as to the mechanism of the ejection process, Baade, partly in cooperation with Humason, has investigated the 'shells' around Nova Herculis (1934), Nova Persei (1901), Nova T Aurigae (1891), and R Aquarii. Some of the spectroscopic observations of these objects by Humason have required exposure times of 20 hours.

*Nova Herculis.* Photographs obtained at the Cassegrain focus of the 100-inch in the summer of 1942 showed the true ring structure of the shell very clearly. Those taken in red light proved that, in contrast with the  $N_1$  and  $N_2$  emissions of  $[O III]$ , which are uniformly distributed throughout the shell, the strong red emissions are restricted to a wide band along the minor axis and to two faint clouds symmetrically arranged at the ends of the major axis. Spectra of the shell show that the  $[N II]$  lines  $\lambda 6548$  and  $\lambda 6584$  are responsible for these localized emissions.

As previously reported, photographs of the shell in the light of the  $N_1, N_2$  lines have shown no trace of two components observed visually by Kuiper and others up to 1942. Baade and Humason, however, have succeeded in recording them in the spectral images of the shell, which permit the detection of very weak condensations because the light emanating from a given point of the nebular image is spread out by the spectrograph owing to the range in velocity. On spectra with the slit along the major axis of the envelope, the two Kuiper components are outstanding features in the  $N_1$  and  $N_2$  lines.

With the newly constructed image rotator, a series of spectra has been obtained which, proceeding in steps of  $15^\circ$  in position angle, covers the whole shell. No additional condensations have been found, although components 1 to 2 magnitudes fainter than those of Kuiper should have been easy to detect.

*Nova Persei (1901).*—Baade and Humason have investigated the expansion of the shell around Nova Persei by measuring the motions and radial velocities of about a dozen well defined condensations. The results show that practically all the ejected matter is contained in the rear part of the southwest quadrant. The motion of this main fragment of the shell seems to have been uniform since the outburst. The thickness of the shell, in terms of its outer radius, is 0.22, practically the same as that found for Nova Aquilae. The distance of the nova, derived from the expansion data, is  $470 \pm 28$  parsecs, and its luminosity at maximum was  $M = -8.4$ .

*Nova T Aurigae (1891).* The close similarity in general behavior between Nova T Aurigae (1891) and Nova Herculis led Baade to undertake a search for a possible shell. Such a shell about  $12''$  in diameter was discovered, and, although faint, is by no means a difficult object to photograph.

Like the shell of Nova Herculis, it is elliptical, a fact which suggests that the rotation of the star plays a role in cases in which the ejection of the shell extends over several months. A calculation based on the present diameter of the shell and the velocities observed during the outburst gives a distance for T Aurigae of  $800 \pm$  parsecs and a maximum luminosity of  $M = -5.3$ . Like Nova Herculis, T Aurigae is a nova of rather low luminosity. This result confirms earlier indications that slowly fading novae of this type are several magnitudes less luminous than rapidly fading novae of the Nova Aquilae type.

*R Aquarii*. In a previous report Hubble called attention to definite changes in the nebulosity surrounding R Aquarii appear-

ing on photographs separated by 17 years. Although outward motions seemed to be involved, the nature of the changes was not altogether clear. During the past season Baade obtained an excellent plate of the nebulosity which matches closely a similar plate taken by Hubble in 1921. A comparison of the pair in the stereocomparator shows clearly that the whole outer nebulosity is expanding. Evidently it was ejected during a major outburst of the blue companion of R Aquarii, which still shows signs of ejection, as indicated by its recent P Cygni type of spectrum.

Sanford has devoted much time to observations and measurement of the spectra of Nova Cygni (1942) and Nova Puppis (1942), and has published some of the results of this work.

## EXTRAGALACTIC NEBULAE

### PHOTOMETRY

To facilitate strict intercomparisons between members of the local group of galaxies, Baade has begun to transfer the photometric scale of S.A. 68 to both the Andromeda nebula and Messier 33. The intercomparisons of S.A. 68 with the Andromeda nebula are almost completed, and those with Messier 33 should be finished during the coming season. As a check on the magnitude scale in NGC 6822, intercomparisons with S.A. 136 are under way. The scale in this Area will be tested and extended by the platinum half-filter method.

Continued search for variables in some of the near-by dwarf galaxies has resulted in the discovery of two faint Cepheids in the Sextans system. They will be very important in fixing the upper limit of luminosity (brightest stars) in systems of low stellar content.

These last investigations, which require long exposures on the fastest available

plates, would probably have been impossible under normal conditions on Mount Wilson. Since the dimout of the Los Angeles valley, however, the Observatory enjoys again a perfectly dark sky except for a trace of illumination close to the southwestern horizon. As a result, direct exposures with the reflectors on the fast Eastman 103a-O plates, formerly limited to about 45 minutes, can now be extended to 90 or 120 minutes. The corresponding gain in limiting magnitude is best illustrated by some plates of the Andromeda nebula which for the first time show the hitherto unresolved inner part of the nebula sprinkled with a multitude of faint stars just below the twenty-first magnitude.

### SPECTROSCOPY

Spectra of 36 nebulae have been photographed by Humason during the year. Most of these were taken on a small scale (500 A/mm), but 8 are with a dispersion of 220 A/mm and 2 of 65 A/mm.

The number of extragalactic nebulae whose spectra have been photographed at Mount Wilson now totals 406. Included are practically all the brighter objects within reach at Mount Wilson, and many objects of types E and Sa which require less exposure time than late-type nebulae. It is planned to continue the Mount Wil-

son observations until 500 velocities have been obtained. Additional observations will necessarily be of fainter and later-type nebulae, and these should make the collection as a whole a more homogeneous group with respect to nebular type and apparent brightness.

## PHYSICAL LABORATORY

### RARE-EARTH SPECTRA

The spectrum of dysprosium from  $\lambda 2970$  to  $\lambda 8280$ , given by the arc, spark, and electric furnace at various temperatures, has been photographed by A. S. King. From a study of these spectrograms 527 of the stronger lines of Dy II have been identified. Since most of these lines appear at the moderate excitation of the electric furnace, they are presumably from low atomic levels, and the list should include lines to be expected in solar and stellar spectra. Ninety-five lines having the most decided low-level characteristics were compared by Mrs. Sitterly with her revised solar data, and 57 were identified in the solar spectrum. A temperature classification of the rich spectrum of Dy I is now in progress.

Much progress has been made by Dr. Russell in the term analysis of the spectra of neutral and ionized gadolinium, an element which is of considerable astrophysical interest. Several hundreds of lines have been classified according to energy level.

Lines of two previously unrecognized elements in the sun, ionized thorium and neutral gold, were identified through co-operative work of Mrs. Sitterly and A. S. King. For thorium, the necessary data involved the photographing of arc and spark spectra from  $\lambda 2750$  to  $\lambda 7600$  for the segregation of Dy I and Dy II lines, and of the furnace spectrum within the same range

for the selection of the more sensitive lines. The observation by Babcock and Mrs. Coffeen that the gold line  $\lambda 3123$  is strengthened in sunspot spectra supplied confirmatory evidence that this element is present in the sun.

### BAND SYSTEMS OF CN

The violet and red band systems of CN, the latter very prominent in N-type stars, are being examined by A. S. King under a wide variety of conditions in the electric furnace. In emission, the red bands, as compared with the violet system, show relatively high intensity at low temperature. The conditions for their appearance in absorption require further study.

### RULING MACHINES

The ruling machines have been adapted by Babcock and Prall to the construction of special kinds of gratings and to relatively coarse spacing. Some of the work has been for military purposes, but has immediate application to the manufacture of bright gratings. In particular, the microscopic study of ruled surfaces has led to better control of the intensity distribution in the different orders, more especially the first and second orders, which are used in stellar spectrographs.

The data (see table) concerning the

brightness attained in some of the best gratings are of interest. The results are for the green region of the spectrum. Comparison with data collected by Baly shows that the spectra from these gratings are as bright as spectra of the same dispersion formed by prisms.

Approximate grating space	Order	Percentage of incident light in spectrum	Equivalent number of prisms*
1/600 mm	1 or 2	30 to 60	4
1/300 to 1/400	1	70	2

\*Number of dense glass prisms with 60° refracting angle having same mean dispersion as grating.

## MAINTENANCE AND CONSTRUCTION

About 5 per cent of the time of the instrument shop and 3 per cent of the time of the optical shop have been devoted to the normal work of the Observatory. The remainder has been given to the construction of optical instruments and optics for the Office of Scientific Research and Development, and for the Army. Most of the instruments have been designed by Edgar C. Nichols with the assistance of Harold S. Kinney. Albert H. McIntire has remained in charge of the instrument shop, and on the retirement of John S. Dalton the direction of the optical shop was assigned to Donald O. Hendrix.

Very little new apparatus has been constructed during the year. An optical device for rotating the image at the Cassegrain focus of the 100-inch telescope has been designed and completed. It has proved valuable in observations of several nebulae, including the elliptical nebula

around Nova Herculis. For spectroscopic observations the effect amounts to a rotation of the slit.

### BUILDINGS AND GROUNDS

Apart from essential repairs, painting, and general maintenance, little construction has been done in Pasadena or on Mount Wilson. The temporary closing of the Observatory buildings to the general public has reduced greatly the demands upon the operating force on the mountain. As a result, A. N. Beebe, superintendent of construction, Sidney A. Jones and Kenneth de Huff, engineers, and E. W. Hartong, truck driver, have all been able to take part in the production of military equipment in the instrument shop in Pasadena.

A refrigerator for photographic plates has been purchased and placed on the ground floor of the dome of the 100-inch telescope.

## THE LIBRARY

During the year, 198 volumes were added to the library, 91 by purchase, 41 by gift, and 66 by binding, making a total of 15,055 volumes. Because of the war, only a few publications have come through from

foreign observatories and research institutions, and even those from America are materially reduced in number. Periodicals received currently number 98, of which 30 are gifts or exchanges.

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## SPECIAL PROJECTS: ASTRONOMY

DIRK BROUWER, Yale University Observatory, New Haven, Connecticut. *Program for the determination of systematic corrections to fundamental catalogues from observations of minor planets.* (For previous reports see Year Books Nos. 40 and 41.)

The number of plates obtained for this program during the year was 613, of which 236 were secured at the Yale Southern Station in Johannesburg, 192 at New Haven, and 185 at the Allegheny Observatory of the University of Pittsburgh. The number of plates measured during the year was 222, of which 78 were measured by Miss Ruth Huff and 144 by Dr. Gustav Land.

The number of measured plates is considerably lower than last year. This decrease is entirely due to the impossibility of making regular shipments of plates from South Africa, and to the depletion of the staff of assistants at the Yale Observatory because of their employment elsewhere.

The Thomas J. Watson Astronomical Computing Bureau has been occupied to full capacity on war projects, and therefore could not undertake any of the computations that they would have performed for this program in normal circumstances. This necessitated the computation at Yale Observatory of numerical integrations of three planets. It is fortunate that the pro-

gram of integration was so far advanced before the Computing Bureau was changed over to wartime operation. Otherwise the task of keeping up the integrations for the preparation of current ephemerides might have been too heavy for the Observatory.

Dr. Land has nearly completed a discussion of the observations of (57) Mne-mosyne.

The asteroid program is intimately connected with the zone catalogue program of Yale Observatory, since the star positions obtained in the zone catalogue program are used in the reduction of the photographic positions of the asteroids. Volumes 13 and 14 of the *Transactions of the Astronomical Observatory in Yale University* were published in June 1943. They contain the positions and proper motions of 28,857 stars between declinations  $20^{\circ}$  and  $30^{\circ}$  south. Approximately 60 per cent of the total number of stars in the zone catalogue program between declinations  $30^{\circ}$  north and  $30^{\circ}$  south have now appeared in printed catalogues.

S. A. MITCHELL, University of Virginia, Charlottesville, Virginia. *Astronomical studies at the Leander McCormick Observatory.* (For previous reports see Year Books Nos. 38 to 41.)

It is a most curious fact that in the present state of astronomical investigation we know more concerning the general structure of certain external galaxies than we know about our own Milky Way system. In an external galaxy well situated and not too distant, we can see at a glance where the condensations lie and just how large and bright is the nucleus when com-

pared with the outer part. In our own galaxy we are confused by the presence of multitudes of faint near-by stars, and by clouds of interstellar dust which blot out many parts of the Milky Way, including much of the most interesting region of all, the nucleus.

Two contributions toward the eventual clarification of our own galactic structure

have been made at this observatory during the year. A study of the motions of 82 dwarf M stars, discovered by the characteristic appearance of their spectra on plates taken with the 10-inch Cooke prismatic camera, reveals that their average velocity in space is considerably smaller than previously had been supposed. It now appears that the mean kinetic energy of the dwarf M stars is about equal to that of the A-type stars. This fact suggests that equipartition of energy may obtain among all main-sequence stars.

An interesting confirmation of this hypothesis has been found in the spectral statistics of the second McCormick general proper motion program, now nearing completion. Thus it seems certain that the apparent distribution of stars of the main sequence perpendicular to the galactic plane is just about what might be expected on the assumption that the stars behave like molecules in an isothermal atmosphere. The relatively massive A stars are highly concentrated toward the galactic plane, while the somewhat less massive F stars at the same distance are less concentrated, and the degree of concentration closely approximates that predicted from the kinetic theory. Further confirmation of the same sort was found in the Bergedorf spectral statistics, which extend to fainter stars than can be investigated from the McCormick spectra. It appears that the thirteenth-magnitude G stars, the great majority of which belong to the main sequence, concentrate rather less than the F stars at the same distance, in fact, just about as would be expected as a resultant of their smaller average mass.

Stars of the giant branch, on the other hand, have much larger kinetic energies and correspondingly smaller galactic concentration. It seems to follow that the galactic star clouds must be composed of a much higher percentage of dwarfs than

has hitherto been supposed. Also it seems that the relatively rare red giants constitute a separate system of their own. This is in line with current astrophysical conjectures as to the different origin of giants and main-sequence stars.

Continuing his search for invisible companions of dwarf M emission stars, Dr. Dirk Reuyl has made a careful discussion of the McCormick photographs of Cincinnati 1244, first reported on briefly two years ago. From 109 plates spread over the years from 1915 to 1942, he found a faint companion with a mass of only three-hundredths of that of the sun. The period, tentatively fixed at 26.5 years, will be revised by the help of future observations. In last year's report (Year Book No. 41) Drs. Reuyl and Holmberg described a third body in the system of 70 Ophiuchi with the very diminutive mass of one-hundredth that of the sun. These two tiny stars found at the McCormick Observatory are of smaller mass than the third object in the system of 61 Cygni, which has a mass one-sixtieth of that of the sun, and was announced by Strand of Swarthmore as "planetary" on account of the similarity to the mass of Jupiter. Apart from the bodies in our own solar system, these three celestial objects are the only ones yet known that have masses less than one-tenth of the solar mass.

Henry Norris Russell has investigated the probable physical characteristics of such a small celestial body in orbital motion around a more massive primary. He concludes that in internal constitution the object of small mass is probably more similar to a star than to any of the planets in the solar system. However, he argues, since at most it is only feebly self-luminous and must shine mainly by reflected light, it is within the bounds of accepted usage to call these small objects "planets."

Visitors to the observatory during the year included Miss Edith M. Janssen, of

Vassar College, and Dr. P. C. Keenan, both of whom made investigations with the spectra obtained by the Cooke prismatic camera. In the summer of 1943, Dr. Mitchell was given the use of the 60-inch reflector at Mount Wilson Observatory in order to obtain radial velocities from spectra of tenth-magnitude A and K stars included in the second McCormick proper motion program.

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# GEOPHYSICAL LABORATORY

*Washington, District of Columbia*

L. H. ADAMS, *Director*

As was stated in the previous annual report, the customary activities of the Laboratory have been discontinued, and all space and facilities have been applied to a variety of investigations aimed at the development of improved devices of warfare and including both fundamental research and the application of basic principles. This work is being carried out under the auspices of the National Defense Research Committee of the Office of Scientific Research and Development, under contracts between the Institution and the OSRD. The investigations utilize the full-time services of all the regular personnel of the Laboratory, except five staff members who have taken important assignments in other government activities directly related to the war effort. The Laboratory building also houses a governmental office, namely that of NDRC's Division One, which has supervision over an extensive

and closely coordinated series of investigations, of which those under one of the Laboratory's contracts are a part.

The situation continues as reported last year, the principal difference being an expansion of the program. About 50 additional employees, including scientific investigators, technicians, and office workers, have been engaged at the Laboratory, on a temporary basis, for the purpose of carrying forward the investigations with all possible speed. The particular items of research and development have been undertaken for the most part at the direct request of the Army and Navy and in close cooperation with these agencies.

During the past year it was found practicable to put in final form for publication a few articles dealing with the previous work of the Laboratory. Abstracts of these papers follow.

## SUMMARY OF PUBLISHED WORK

- (1072) A review of "X-ray crystallography, an introduction to the investigation of crystals by their diffraction of monochromatic X-radiation," by M. J. Buerger. George Tunell. *Amer. Mineralogist*, vol. 27, pp. 780-781 (1942).

Professor Buerger's book is devoted to the geometry of the space patterns in crystals; it thus deals with the crystal class, the space lattice (its type and dimensions), and the space group, and will be very useful to all those having to investigate crystals with X-rays.

The moving-film methods, which permit the straightforward determination of the geometric properties mentioned above, occupy the largest part of the book. They include the

Weissenberg method, the Sauter method, the Schiebold method, and the DeJong and Bouman method. The earlier rotation and oscillation methods are also discussed in detail. The equi-inclination Weissenberg method receives the largest amount of space devoted to any one method; the reviewer considers this to be in keeping with its comparative utility. In a section entitled "Advantages of taking Weissenberg photographs by the equi-inclination method," Professor Buerger writes: "It is uniquely possible for the equi-inclination method to record central lattice rows as straight lines, and thus permit easy reconstruction of the reciprocal lattice, and also, more generally, to record the lattice rows of all layers as curves of similar shape, and

consequently permit indexing directly on the film." These important advantages of the equi-inclination method he discovered several years ago. Additional advantages of the equi-inclination Weissenberg method over the methods involving perpendicular incidence might well have been mentioned explicitly at this point; for example, with the equi-inclination method there is no blind area around the rotation axis in any reciprocal lattice layer, so that no planes of low indices fail to register on the diffraction photographs. (Analysis of intensities is left outside the scope of the book, but since some mention is made of intensity factors it may be noted in passing that it has been shown by the reviewer that the equi-inclination method has equally important advantages in respect to the intensities of the diffraction spots.) Besides the chapters dealing with experimental methods, others are devoted to the following topics: Some geometrical aspects of lattices; the diffraction of X-rays by crystals; space-group extinctions; the reciprocal lattice; geometrical interpretation of Bragg's Law—application of the reciprocal lattice to the solution of X-ray diffraction problems; the geometry of oblique cells and their reciprocals; the experimental determination of the lattice constants belonging to the oblique systems; the theory of attaining precision in the determination of lattice constants; the precision determination of the linear and angular lattice constants of single crystals; the theory and interpretation of reciprocal lattice projections.

- (1073) A graph for determining angle and direction of pitch of lineations in the field. Earl Ingerson and O. F. Tuttle. *Amer. Mineralogist*, vol. 28, pp. 209-210 (1943).

When no lineation compass is available, the direction and angle of pitch can be determined from the dip and strike of the *s*-plane containing the lineation, and the angle that it makes with the strike of the *s*-plane, measured in that plane. Use of a prepared graph, such as is described here, requires less equipment than making a constructional solution for each determination with a stereo-

graphic or a gnomonic projection, or by descriptive geometry. Furthermore, it is faster and just as accurate.

- (1074) Solubility of solids in water vapor. George W. Morey. *Proc. Amer. Soc. Testing Materials*, vol. 42, pp. 980-988 (1942).

A discussion of the theory underlying the solubility of solids in steam under high pressure, with special reference to those systems of interest in the control of deposits in high-pressure boilers and turbines.

- (1075) Iridescent garnet from the Adelaide Mining District, Nevada. Earl Ingerson and Julian D. Barksdale. *Amer. Mineralogist*, vol. 28, pp. 303-312 (1943).

Garnets from a lime-rich layer in the contact zone of a granodiorite stock near Golconda, Nevada, show brilliant iridescence both on striated crystal faces and in thin section. They have a birefringence a little more than a third of that shown by orthoclase ( $0.0025 \pm$ ), and show, superposed on the triangular segments that are common in lime-contact garnets, lamellae that look like polysynthetic twinning. Universal-stage measurements show that the lamellae are parallel to (110) and (111). It appears that the iridescence is due to the very fine (111) lamellae and that it is more intense where the individual lamellae are finer. Sections of the garnets heated in a furnace show a decrease in birefringence beginning at about 1060° C and continuing practically to the melting point, just below 1250° C. In thin sections that have been heated almost to the melting point (1225° C) the birefringence is very low, but the twinning lamellae and iridescence are still visible.

- (1076) Preparation and properties of some compounds in the system  $H_2O-Na_2O-P_2O_5$ . Earl Ingerson and George W. Morey. *Amer. Mineralogist*, vol. 28, pp. 448-455 (1943).

Optical properties of all known compounds of  $Na_2O$  and  $P_2O_5$ , both hydrous and anhy-

drous, are given. For eight of these the data are taken entirely from the literature; eight have been restudied; five are here described optically for the first time. Crystallographic and density data are given for some of them.

The methods of preparing twelve of these compounds are given; and for the others, methods can be obtained from the literature cited. The nomenclature of these phosphates is discussed. Refractive indices are given for eleven glasses in the system  $\text{NaPO}_3\text{—Na}_4\text{P}_2\text{O}_7$ .

(1077) The compound merwinite ( $3\text{CaO} \cdot \text{MgO} \cdot 2\text{SiO}_2$ ) and its stability relations within

the system  $\text{CaO—MgO—SiO}_2$ . (Preliminary report.) E. F. Osborn. Jour. Amer. Ceram. Soc., vol. 26, pp. 321–332 (1943).

Preliminary investigations on compositions between  $\text{Ca}_2\text{SiO}_4$  and akermanite ( $\text{Ca}_2\text{MgSi}_2\text{O}_7$ ), between merwinite ( $\text{Ca}_3\text{Mg}(\text{SiO}_4)_2$ ) and akermanite, and between merwinite and monticellite ( $\text{CaMgSiO}_4$ ) show that a field of merwinite appears on the liquidus surface of the system  $\text{CaO—MgO—SiO}_2$  and that merwinite melts incongruently at  $1575^\circ \text{C}$  to  $\text{Ca}_2\text{SiO}_4$ ,  $\text{MgO}$ , and liquid.

(1078) Annual Report for 1942–1943.

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TUTTLE, O. F. See INGERSON, E.





# DEPARTMENT OF TERRESTRIAL MAGNETISM

*Washington, District of Columbia*

JOHN A. FLEMING, *Director*

## SUMMARY

The retarding effect of the war on the progress of geophysical research, indicated in last year's report, has continued to influence progress in geomagnetism and geoelectricity during this report-year, July 1, 1942 to June 30, 1943. Difficulties of communication between countries have increased, and scientific investigations have been largely turned toward developments more nearly connected with the requirements of modern warfare. Fortunately, many established organizations and observatories have found it possible to maintain at least part, if not all, of their programs, so that the loss of continuity in accumulating data is not too serious. Unfortunately, the war does prevent cruising of the British Admiralty magnetic-survey vessel *Research*, and the resulting inability to obtain additional data over the oceans, to determine the important changes with the years in the geomagnetic elements, is most serious—the more so because of the need for these data in maintaining isomagnetic charts, so vital for purposes of navigation, defense, and offense.

It is gratifying that use in the emergency is constantly growing for work done since the initiation of the Department in 1904. The past year has emphasized particularly the increasing importance of the observatories. At least 95 per cent of the services of personnel and all the laboratory, shop, observatory, and building facilities of the Department were devoted to investigations and solutions of war problems. Though this apparently has hampered the continuation of the regular program, many of the

results obtained in connection with special war problems are of great peacetime value.

As in previous years during the war, and in conformity with the action of the Trustees, the services of the regular scientific and administrative personnel and the use of facilities have been contributed without charge to the government. These services during the report-year totaled over 34,400 hours for the scientific staff and over 4800 for the administrative staff; the corresponding totals for the whole period of the emergency since August 1940 were 91,000 and 16,600 respectively. In addition, the personnel of the Watheroo, Huancayo, and College observatories were engaged in work proving of great use in the war effort. Twelve of the regular and temporary scientific personnel were on leave of absence in war activities on June 30, 1943. The Department was engaged on ten nonprofit contracts with the Army, Navy, and Office of Scientific Research and Development, on urgent projects. To assist in the development of these projects, additional professional, computing, and clerical assistants were engaged. The maximum number of the staff during the year was 247. Thanks must again be extended for the generous action of universities and industrial organizations in granting leaves of absence and extending technical advice, as well as to many Selective Service boards for granting deferments of professionally trained men.

## REVIEW OF YEAR'S PROGRESS

*Cosmic relations.* Cosmic data were assembled and analyzed (1) to increase the

understanding of solar, geomagnetic, and ionospheric relationships, and (2) to improve the technique of short-term forecasting of ionospheric disturbances. Electron-density in the ionospheric regions has continued to diminish as the minimum of the 11-year cycle of activity approaches. Some magnetic and ionospheric disturbances occurred, and the isolation of solar regions responsible for terrestrial disturbances was simplified by the reduced solar activity. Solar corona of high intensity and observed activity in flocculi on the disk were found apparently the most promising criteria for anticipation of magnetic disturbances. The beginning of the new sunspot-cycle indicates an early increase of solar, magnetic, and ionospheric activity. Ionospheric absorption, sporadic E-region ionization, aurora, and magnetic bays and character-figures were found to be related in fairly definite ways, in most cases approximating direct proportionality. Methods of obtaining accurate visual records of magnetic phenomena were developed, and one visually recording instrument was constructed. Useful operational material regarding ionospheric disturbances affecting radio circuits was supplied to the Army and Navy.

*Geomagnetic investigations.* Tables of the changes in annual mean value of the geomagnetic field with sunspot-cycle, the average annual variations, daily post-perturbations, and average solar daily variation for the 38-year period from 1905 to 1942 were nearly completed. A world-chart of magnetic vertical intensity was constructed. Instruments for the measurement of short-period magnetic fluctuations were designed, constructed, and placed in operation.

A visually recording magnetograph was developed. The development of a portable magnetograph well suited for field-use was begun. A magnetic variometer of universal

pattern was designed and constructed, incorporating a valuable improvement in the detecting element for vertical intensity, and suited to the making of measurements on a moving platform such as is available aboard ship.

It was found from theory that for geomagnetic fluctuations of periods of order 50 seconds, only slight magnetic shielding is furnished by the first few hundred meters of sea-water. A practical formula for prediction of geophysical time-series was evolved.

*Terrestrial electricity.* Improvements were made in methods and instruments for measuring the rate of ionization. The technique of preparing quartz suspension-systems for sensitive instruments was improved.

Further analyses of data obtained at the observatories, particularly Watheroo, led to more satisfactory interpretations of several characteristic aspects of atmospheric electricity at specific stations. Study of observed variation with wind-velocity of the atmospheric-electric elements at Watheroo has improved understanding of effects of smoke distributed in the atmosphere. Evidence was obtained from discussions of atmospheric-electric data at Watheroo confirming the hypothesis that radioactive matter accumulates in the lower air during times of calm and is mixed with the higher layers of air during times of higher wind-velocity.

The theory and limitations of the use of the columnar resistance of the atmosphere were examined and methods of analysis improved; interpretations previously made of some atmospheric-electric phenomena in terms of columnar resistance of the atmosphere were placed on a better foundation, and in some cases modified or extended.

It was estimated from experimental investigations that the particles in exhaled

breath—presumably the chief factor in reducing the electrical conductivity of the air in occupied rooms—are much larger than the ordinary nuclei of condensation, being  $3 \times 10^4$  times the size of the large ion of the atmosphere; this fact may account for the failure of some investigators to detect these particles.

*Ionosphere.* The value of the ionospheric program undertaken by the Department some eight years ago was emphasized by urgent need of particulars regarding the relations of ionospheric variations and disturbances. Many confidential studies for operational application were made, and the results from the Watheroo, Huancayo, and College observatories were advantageously used in these. The Department was asked to establish additional stations, and arrangements were made for these to begin operation within a few months—a considerable task as regards equipment, obtaining and training of observers, and housing.

*Nuclear physics.* The demands of the emergency for personnel restricted theoretical work in nuclear physics. The need for an operating cyclotron in the region of Washington to meet certain war requirements became more pressing, and all efforts of the few members of staff available in laboratory and shop were concentrated on completing the equipment for actual use. Excellent progress was made, and preliminary tests indicated satisfactory operation within the year. The continued cooperation of the National Cancer Institute, in continuing the assignment of Physicist D. B. Cowie of its staff, and of the Naval Research Center must be credited with a large measure of the progress made.

*Observatory- and field-work.* The complete magnetic, auroral, and ionospheric observatory established in collaboration with the University of Alaska at College,

Alaska, in July 1941 was maintained in full operation. Special studies relating to ionospheric problems were made by the Observatory's staff, and charts showing graphically the systematic diurnal and seasonal changes occurring in the transmission-characteristics of the ionosphere were prepared.

The extensive geophysical programs at Huancayo and Watheroo magnetic observatories were continued, and all resulting data were promptly communicated and made available for emergency use.

Because of commercial requirements, it was necessary to end early in 1943 the long series of earth-current records obtained at the Tucson Magnetic Observatory, a series made possible by cooperation with the American Telephone and Telegraph Company, the Mountain States Telephone and Telegraph Company, and the United States Coast and Geodetic Survey. Cooperation with the Survey in the atmospheric-electric program was continued.

Maintenance of international magnetic standards at the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey was effected through the Division of Geomagnetism and Seismology of the Survey.

Though no field-work other than at the observatories could be undertaken, it was possible to assist various governments, through loans of magnetic instruments, in undertaking new magnetic surveys and obtaining repeat-observations at established stations.

*Miscellaneous.* The Department was fortunate in having on active duty three of its retired staff—J. W. Green, A. Smith, and W. F. Wallis—whose services were of great value in the emergency.

Philip E. Brooke, who so faithfully served as caretaker and night watchman for 25 years, retired from active duty on March 31, 1943.

## INVESTIGATIONAL AND EXPERIMENTAL WORK

### TERRESTRIAL MAGNETISM

Those of the regular staff engaged at Washington on investigations and experiments in geomagnetism were Fleming, J. W. Green, Johnston, Miss Lange, McNish, Scott, Torreson, Vestine, Wallis, and Wells; Shapley, of the temporary staff, made substantial contributions. McNish gave all his time to supervision of temporary employees engaged on war research for the National Defense Research Committee. Torreson was on leave with the Office of Scientific Research and Development; the others named averaged at least 95 per cent of their time on matters directly or indirectly related to the war effort. Many of these matters had to do with instrumental techniques and theoretical investigations of first importance to geomagnetism. A certain amount of other research was accomplished and is reported below.

#### PERMANENT FIELD

The study of methods of analyzing and interpreting the geomagnetic field was continued. Data on magnetic anomalies in various parts of the world were compiled for determining their relation to geological formations. An isodynamic world-chart of vertical intensity for epoch 1940 was prepared. Isoporic charts of recent epoch were found regionally to show great changes in form from those prepared by the Department for epoch 1922. A simple method for prediction and extrapolation of certain types of geophysical time-series was evolved.

The average monthly values for all available stations of the solar daily magnetic variation on quiet days,  $S_q$ , were derived for the mean of the 12 years from 1922 to 1933. Detailed examination was made of the daily variability of the cur-

rent-system for  $S_q$  with reference to the effect of this variability on the reduction of field-observations to mean of day. An anomalous condition in  $S_q$  similar to that at Huancayo in the Western Hemisphere, though less marked, was found to exist at Manila in the Eastern Hemisphere. The phase of  $S_q$  was determined to be practically independent of the amplitude of  $S_q$ , apart from seasonal influences.

Daily, weekly, monthly, and annual ranges in the geomagnetic elements in any latitude were derived, and the probabilities of ranges of various magnitudes deduced. An extensive study was made of recorded frequencies and magnitudes of geomagnetic fluctuations with durations of ten seconds to several hours. It was found that equipment heretofore generally used at observatories is adequate for detecting fluctuations of durations greater than ten seconds.

The reductions and discussions of the magnetic data obtained by the United States Antarctic Expedition of 1939-1941 were completed, and the manuscript was prepared at the Department by Fitzsimmons, magnetic observer of the Expedition, and forwarded for publication to the United States Department of the Interior.

#### MAGNETIC DISTURBANCES AND COSMIC RELATIONS

The latitude-distribution in amplitude and phase of the yearly changes in the annual means of geomagnetic elements with sunspot-cycle was determined and estimated for each year from 1905 to 1940. A similar derivation was made for all latitudes for the annual variation and post-perturbation. Estimates were made of the induced currents flowing in the oceans due to short-period geomagnetic fluctuations.

A group of professional associate workers, under the supervision of Vestine and Miss Lange with the assistance of others of the regular staff, especially Johnston and Scott, compiled data on the frequencies of geomagnetic fluctuations of various amplitudes and durations and on the reduction of geomagnetic data to epoch.

Magnetic activity during the report-year showed recurrence-tendencies of disturbed and quiet periods. The tendency for magnetic disturbances to recur at intervals of about 27 days was very pronounced with the smaller storms during this period of minimum solar activity. One storm-sequence started on July 14–16, 1942, and reached its maximum on October 28–31 with the severest storm of the report-year. It later divided into two disturbances spaced several days apart, and was traced into March 1943. The disturbed period August 16–27 recurred in September and again in October. Another disturbed period, centered about April 3, repeated itself in the succeeding three cycles. During the year there was a high percentage of disturbed days, but no really large storms. The previous 12-month period had three storms of greater intensity than the one of October 29, 1942, but there were 14 per cent more days appreciably disturbed in 1942–1943 than in 1941–1942. Thus, rather than by severe magnetic storms with their spectacular effects, the past year was characterized by mild disturbances during a relatively high percentage of the time.

General comparison and discussion were made of the following geomagnetic and solar phenomena during July 1, 1942 to June 30, 1943: (1) American magnetic character-figure,  $C_A$ , (2) relative sunspot-number,  $R$ , (3) area,  $S$ , of sunspots in the central zone, (4) area,  $F$ , of flocculi in the central zone, (5) average total area,  $P$ , of prominences referred to central me-

ridian of date, (6) average intensity,  $C$ , of the green coronal line referred to the central meridian, and (7) transmission-disturbance figures,  $TD$ . The solar data are not homogeneous because of differences in observing conditions; the resulting graphs are similar at many times but differ conspicuously in detail. Many instances of nearly simultaneous features are evident, the best being at about November 2, 1942; others are August 23, September 18, November 29, December 26, 1942, and March 23, April 6, April 21, and May 17, 1943. There are, however, as many more cases where magnetic disturbances had no obvious solar cause, and cases where solar activity had no magnetic counterpart.

Magnetic activity and properties of the ionosphere parallel roughly the 11-year solar-activity cycle. The last minimum in that cycle occurred in 1933 and another minimum is due between 1943 and 1945. It is of considerable practical value to the field of communications to foretell the minimum and hence the time when an increase in solar and geomagnetic activity may be expected. Progress of the activity-cycle was compared with the magnetic index  $u$  (smoothed), and with average maximum critical frequency of the  $F_2$ -layer ( $09^h$ ,  $75^\circ$  west meridian time) at Huancayo. The parallelism of critical frequency, which is proportional to the square root of electron-density, with sunspot-number was much closer than that of either factor with the magnetic-index curve, and suggests the preferability of ionospheric measurements as direct indicators of terrestrial effects of sunspot-activity.

Radio "blackouts" in polar regions are found to occur during magnetic bays—typical magnetic disturbances of short duration which are preceded and followed by generally undisturbed magnetic conditions. These bays are very pronounced near the auroral zone, although their magnetic ef-

fects extend to equatorial regions. The similarity of these blackouts to the well known daylight fade-outs is marked. Both effects appear to be caused by absorption due to intense ionization of the lower ionosphere. The polar blackouts, so prevalent during all magnetic disturbances, must result from particle bombardment (or equivalent) from the Sun.

#### INSTRUMENTAL DEVELOPMENTS

The close relations between magnetic and ionospheric disturbances have indicated the need for a visually recording magnetic variometer of simple construction. An instrument of this type would permit immediate assessment of degree of disturbance and application of the observed correspondence between ionospheric and magnetic phenomena, especially when operated in high latitudes. The onset of a magnetic disturbance is usually recognizable from standard magnetic records before the storm has reached its major phase. Magnetic recordings, however, are made on photographic paper, and the daily traces are not available for inspection until the paper has been processed. This is generally too late for immediate application of established relations. A visual recording variometer would overcome this difficulty and make possible short-term evaluation of expected local ionospheric disturbances. Practical use of the 24-hour recurrence-tendency of magnetic bays in polar regions is one such possible application.

One type of visual recorder incorporating a sparking device to plot changes in the Earth's field was devised. A long platinum-tipped pointer attached to the magnet-system of the variometer moves over a metallic plate as the suspended magnet deflects in the Earth's field. At intervals of about one minute a spark

from the tip of the pointer to the metallic plate makes a record on a sheet continuously moving through the spark-gap. Thus a succession of points burned in the paper makes immediately apparent variation of the Earth's field with time.

In a second method, a photoelectric cell is made to follow the light-beam reflected from a mirror rigidly fastened to the suspended magnet of a variometer. A pen attached to, or synchronized with, the photocell gives a record in ink of the deflections of the variometer. Any unbalance of light falling on a twin photocell results in a movement of the photocell to a new position, seeking a balance. When equal amounts of light fall on both sections of the photocell, the moving pen stops until a change in magnetic field again causes an unbalance. This instrument has attractive remote-recording possibilities. The soundness of the principle was demonstrated by an experimental model, and further development is contemplated.

Another type of visual recorder utilizes special photographic paper which shows a trace, immediately visible through a red filter, of deflections of the light-beam from a standard variometer. A standard hydrographic recorder was adapted for use with this equipment. One instrument was completed, tested, and assigned for field-tests shortly after the end of the report-year.

Variometers were designed for measuring short-period geomagnetic fluctuations by Vestine, Sherman, and Johnston in collaboration with Messrs. Gebhardt and McComb, of the United States Coast and Geodetic Survey. Of major interest was the successful construction of the element for measuring magnetic vertical intensity, along lines formerly less successfully followed by Watson. New detecting elements for horizontal intensity and declination permit the accurate measurement of

geomagnetic fluctuations of periods as short as one-half second. Sudden changes in field such as might give rise to micropulsations not recorded by variometers with slower response can be detected and measured with these instruments.

A new variometer of universal pattern for horizontal intensity, vertical intensity, and declination was designed and constructed with the assistance of Steiner; this involves quartz-fiber detecting elements and quartz supports developed by Sherman. A visually recording magnetograph incorporating this type of universal variometer for horizontal intensity and la Cour variometer for declination was de-

veloped by Vestine, Sherman, and others, along general lines suggested by Fleming and Wells. This design involves a new type of quartz-suspension, with T-shaped ends, permitting highly stable mounting of a magnet-system designed by Sherman. Some features have been used in a new type of portable magnetograph, already in construction, for use in the field as well as at observatories. This kind of magnetograph is much needed for continuous, reliable magnetic records over short periods (one or two weeks) for control and reduction of field-observations, for which records as obtained at widely spaced observatories have proved insufficient.

## TERRESTRIAL ELECTRICITY

The time and personnel devoted to research in terrestrial electricity were further restricted this year by the demands of the war. The full time of Rooney and Torreson was devoted to problems concerned with war research, and Gish, Sherman, and Wait, in addition to maintaining the necessary routine and urgent research of the Section, worked or acted as consultants on several war problems.

### ATMOSPHERIC ELECTRICITY

*Development of instruments, methods, and techniques.* A report was written on the constants, calibrations, and method of operation of a set of precision ionization-meters, designed for various investigations. These meters are now being used by Professor Victor F. Hess, Fordham University, New York, in a study of the radioactivity of earth-materials. Several improvements in the circuits and in the technique of using these meters were developed during the year (Gish, Sherman). Further experimental study (Sherman) of the behavior of a thin-walled ionization-chamber indicates the need of, and points the way

toward, improvement of this instrument. A clarification of some factors which affect the counting of nuclei of condensation and large ions was effected. The technique of making sensitive quartz-fiber systems was considerably improved (Sherman).

The research in atmospheric electricity consisted chiefly in studies by analysis and correlation of observed data and in the interpretation of the results of such studies, as outlined in the following paragraphs.

*Electrode-effect in the atmosphere.* A study (Sherman) of manifestations of the electrode-effect in the air-conductivity registered at the Institution's observatories at times when intense electric fields developed, led to inferences about a parameter—designated the coefficient of combination between small ions and large ions—which appears in the equations for ionic equilibrium. The values of this coefficient heretofore determined by other methods differ so greatly that this approach seemed worth while. The value estimated ( $5.4 \times 10^{-6}$ ) is within the range of the previously determined values. More important, however, is the indication that the value is prac-



tically the same for the three observatories at Watheroo (Western Australia), Tucson (Arizona), and Huancayo (Peru), which differ considerably in altitude (244, 770, and 3353 meters, respectively), as well as in certain other aspects of their environment.

*Columnar resistance of the atmosphere.*

The term columnar resistance is used in some discussions of atmospheric-electric phenomena to denote the effective electrical resistance from end to end of a vertical column of air of unit cross-sectional area. Usually this column is conceived to extend from the Earth's surface to an indefinite height, unless a definite height is specified. This simple concept facilitates the discussion and interpretation of some aspects of atmospheric electricity, but it is valid only when certain circumstances obtain in the atmosphere. Additional assumptions are involved in some methods which have been used to estimate columnar resistance, and in some interpretations. A study of these was made (Gish) to determine their validity in specific cases.

The relative columnar resistance for a given station is the ratio of the columnar resistance there to that for some other station; under certain assumptions it is equal to the inverse ratio of the values of the vertical electric conduction-current at the respective stations. Evidence of a latitude-effect has been previously presented, but this has not generally been taken into account in studies of the relative columnar resistance (generally the resistance for a land station relative to that for the oceans); it was shown that this may lead to anomalous results. In one case the value was only 80 per cent of the corrected value, and without the correction it could not be satisfactorily interpreted. Convenient empirical expressions which accurately describe typical data for the resistance of a column extending from the Earth to a height  $Z$ , as a function of  $Z$ , were found.

The changes in columnar resistance are attributed chiefly to changes of either the concentration or the vertical distribution, or both, of the nuclei of condensation in the lower atmosphere, on the assumption heretofore made of arbitrary forms of distribution. In one phase of the present investigation, forms of distribution were sought consistent with the observed data and conforming to the meteorological or other circumstances probably prevailing at the time and place of observation.

The principal results of further analyses and interpretations of atmospheric-electric data, chiefly for Watheroo (Wait), follow:

*Variation of conductivity and air-earth current with wind-velocity at Watheroo.*

The investigation, reported last year, of the correlation between potential-gradient and wind-velocity at Watheroo was extended this year to include the conductivity and air-earth current. It was found that on smoky days the conductivity is independent of wind for velocities less than about  $4\frac{1}{2}$  miles per hour, but for greater velocities it increases with an increase in wind-velocity. This is approximately the inverse of the relation found for potential-gradient, hence the air-earth current undergoes no marked variation with wind-velocity. These results suggest that the smoke from near-by bush-fires is dispersed in a vertical direction at the higher wind-velocities, with the result that the concentration in the lower layers is diminished, and that in the higher layers of the air is, more or less correspondingly, increased.

On non-smoky days, the air-earth current increased slowly with increase in wind-velocity, particularly for the lower velocities, whereas the conductivity decreased slowly until at velocities greater than about 5 miles per hour it became more or less constant. This suggests that on non-smoky days there was some smoke in the atmos-

phere which had come from more distant bush-fires, but that it had been dispersed horizontally by the wind, the total amount in a vertical column decreasing as the wind-velocity increased. At higher velocities the concentration of smoke apparently approached a limit and the conductivity no longer depended upon wind-velocity.

The ratio of positive to negative conductivity generally decreased with increasing wind-velocity except for velocities less than 3 miles per hour on non-smoky days. This result may be due to the fact that near the ground the concentration of negative ions is reduced by the action of the electric field, but the mixing produced by wind tends to counteract this electrode-effect, to establish a more uniform vertical distribution of the negative small ions, and to cause the number of positive and negative ions at any given height to approach the same concentration. Near the ground, however, this condition is not realized at the highest velocities investigated, since the ratio is still greater than unity.

*Diurnal variation of ionization in the atmosphere.* The observed rate of ionization of the atmosphere at the site of the Department, obtained by use of a thin-walled ionization-chamber, often reached a maximum in the early morning, then diminished to a minimum in the evening. During periods of high wind at night or during the day, this type of diurnal variation did not develop. This observation tends to confirm the theory previously suggested, that the usual diurnal variation of this element depends on the concentration of radioactive matter in the atmosphere near the ground. This concentration is greatest in early morning following a calm night. As the wind-velocity increases during the forenoon, the radioactive matter is scattered and mixed with higher layers of air, and its concentration in the lower layers of air is thus reduced until a con-

dition of calm is approached in the evening. When the wind remains high throughout the night, and also during the daylight hours, the concentration of radioactive matter does not vary and the normal diurnal variation in ionization does not develop.

*Diurnal variation of air-conductivity at Watheroo.* Air-conductivity depends on the rate of ionization and the number of condensation-nuclei present. The data from Watheroo indicate that its normal fair-weather diurnal variation depends primarily on the rate of ionization; on smoky days, however, the variation in the number of condensation-nuclei may be the controlling factor.

*Diurnal variation of potential-gradient in winter at Watheroo.* The average diurnal variation of potential-gradient at Watheroo during the winter is of a type quite unlike and during the summer quite like that found over the oceans. This disparity may be explained as follows: During the fair-weather days at Watheroo, the wind generally diminishes to low velocities toward evening and remains so until early forenoon of the following day, when the velocity increases considerably. During 1927 to 1928, there were 17 fair-weather days on which the wind remained high during both the night and the daylight hours. Comparison of atmospheric-electric data for these and for days of normal type indicates that: (a) The maximum in the normal winter diurnal variation of potential-gradient at Watheroo occurs at about 07<sup>h</sup> GMT (15<sup>h</sup> 120° east meridian time) and over the oceans at about 17<sup>h</sup> GMT. The diurnal variation for the 17 selected days, however, is very similar to that found over the oceans. (b) Between 10<sup>h</sup> and 20<sup>h</sup>, 120° east meridian time, the variation of gradient for normal days in winter at Watheroo is essentially like that for the 17 selected days,

but during the remainder of the day it is quite unlike it, since the potential-gradient values for the normal days fall considerably below those for the selected days. (c) Though the conductivity of the lower atmosphere is also about the same for both classes of days from  $10^h$  to  $20^h$ , that for the normal day is the greater for the remainder of the day. (d) The diurnal variation of air-earth current for the two types of day is similar throughout the entire 24 hours.

These results indicate that the lack of similarity in winter between the diurnal variation of potential-gradient at Watheroo and that over the oceans is due chiefly to the large increase in conductivity at Watheroo during times of low wind-velocity. This increase is to be attributed to a greater rate of ionization caused by an accumulation of radioactive matter in the air near the ground. When the wind remains high throughout the day, its stirring action prevents the accumulation of radioactive matter; hence the variation of potential-gradient on such days is like that over the oceans.

*Diurnal variation of potential-gradient in summer at Watheroo.* The diurnal variation of potential-gradient in summer is nearly in phase with that over the oceans. This seems to contradict the above explanation for the winter type. During the summer, however, condensation-nuclei from smoke tend to counteract the effect of the increase of radioactive matter in the air, because the smoke is most plentiful during the period when the accumulation of radioactive matter is greatest. The accumulation of smoke near the ground tends to decrease the air-conductivity and to increase the potential-gradient. Comparison of the potential-gradient for smoky days in summer at Watheroo with that observed simultaneously over the oceans shows that the former, particularly during the early morning, exhibits a large relative increase.

The presence of smoke in the lower air during the early morning apparently more than neutralizes the effect of accumulated radioactive matter there. Comparison for non-smoky days at Watheroo, however, shows that the potential-gradient is relatively diminished during early morning, the concentration of condensation-nuclei in the lower air not being great enough to counteract completely the effect of the accumulated radioactive matter, provided its distribution with height is not involved.

*Electrical mobility and size of particles from the human breath.* The observed decrease of the electrical conductivity of the air in a room occupied by people has been attributed (Wait) to particles, or nuclei, introduced into the room with exhaled air. Some investigators, using the Aitken nuclei-counter, have not detected such particles in samples from the breath, because those particles are too large to be counted with the types of counter used. The average diameter of the particles, estimated from an experimentally determined value of their mobility, is about 2 microns, or 30 times that of condensation-nuclei or Langevin ions. The mobility derived from the results of specially designed experiments is  $3 \times 10^{-6}$  cm<sup>2</sup> volt<sup>-1</sup> sec<sup>-1</sup>.

#### GEOELECTRICITY

Early in 1943 it was found necessary to discontinue the recording of earth-currents at Tucson because of increased commercial demands for the long-distance telephone lines made available by the Bell Telephone System. Attention was given (Gish) to ways and means for restoring these registrations. It is desirable that registration of earth-currents be continued indefinitely at a few well chosen stations, one of which should be Tucson. Although the accumulated data at Tucson are probably adequate for the study of the more regular phe-

nomena (diurnal variation and annual variation) of earth-currents, additional data are required for investigating the more intense irregular aspects, for example elec-

tromagnetic storms. Some such permanent stations are also needed as controls in other geoelectric investigations likely to be made in the future.

## INVESTIGATIONS OF THE IONOSPHERE AND ITS RELATION TO PROBLEMS OF GEOMAGNETISM

The fundamentals of the program of ionospheric research by the Department are outlined in the report for last year (Year Book No. 41, pp. 54-58). The Earth's magnetic field and long-distance radio communication are mutually influenced by the behavior of the highly ionized regions of the Earth's atmosphere extending from 50 to 500 miles (or more) into space.

The CIW multifrequency equipments at Watheroo, Huancayo, and College continued operation (see pp. 46-52). The receipt of basic data from scalings and tabulations maintained at the three observatories was greatly expedited; thus it was possible to make the results of analyses and discussions more promptly available to military agencies. Arrangements were made to establish four additional stations and to employ and train necessary personnel. The Department's laboratory at Kensington, Maryland, was enlarged to accommodate this work. The transition from peacetime research to wartime projects without radical changes in duties has been a source of satisfaction to all the ionospheric group. When the wealth of material now being assembled for the armed forces becomes available for public discussion and use, knowledge of the ionosphere with its effect on radio wave propagation and the Earth's magnetism will be greatly enhanced.

The unique position maintained by the Department through operation of ionospheric equipment at several field-stations resulted in numerous requests for iono-

spheric data from local agencies and allied governments.

### PUBLICATIONS, CONFERENCES, AND POST-WAR PLANS

A paper was published by Wells on "Effects of solar activity on the ionosphere and radio communications" (*Proceedings of the Institute of Radio Engineers*, vol. 31, pp. 147-157, 1943), originally presented in July 1942 at Cleveland, Ohio. A similar paper was presented at the meeting in February 1943 of the Franklin Institute, Philadelphia.

Certain plans for post-war activities were discussed at various conferences with members and representatives of allied governments. It is probable that post-war developments will see continued close cooperation between the research laboratories and the organizations capable of utilizing available information to immediate advantage.

Other post-war activities in this field probably will be directed toward a better understanding of the fundamental relations between the Earth's magnetic field, the ionosphere, and the Sun—the ionosphere being the medium most responsive to solar activity which in turn affects the Earth's magnetic properties. The study, already under way, of correlations between radio fade-outs, auroras, sporadic *E*-region ionization, and other unusual phenomena will add detail to the composite picture of these relations.

The electronic nature of the ionosphere also affords an opportunity for direct meas-

urement of intensity of the Earth's magnetic field in the ionosphere. Preliminary work done on this problem shows that such measurements are feasible using ionospheric apparatus specially developed to measure the separation in frequency between the doubly refracted components of the exploring radio wave. Such investigations would undoubtedly pave the way to much better understanding of the cur-

rent-systems and other factors affecting geomagnetism.

Wells was in charge of the ionospheric group and was assisted by Peavey and by associates from the temporary staff. Members of the staff in the field are noted in the reports for the observatories. Berkner was on leave of absence during the entire report-year and commissioned as Commander in the United States Navy.

### MAGNETISM AND ATOMIC PHYSICS

Tuve, Hafstad, Heydenburg, Meyer (resigned April 15, 1943), Roberts, Abelson, and L. Schmidt (resigned March 6, 1943) of the nuclear-physics group were assigned or engaged full time during the entire report-year on war-research activities; G. K. Green continued active duty in the Signal Corps of the United States Army. Cowie (assigned from the National Cancer Institute) had charge of work on the cyclotron, in which he was assisted by Ksanda, P. A. Johnson, Buynitzky, F. R. Nichols, and Caherty (to September 30, 1942), all of whom gave full time to constructional assembling and wiring matters. Despite this serious depletion of personnel, good progress was made on the cyclotron. Lack of personnel made it necessary to discontinue for the time being further improvements in the static generator of the Atomic-Physics Observatory and most of the planned program of research in nuclear physics.

#### CYCLOTRON

The Cyclotron Laboratory and its equipment are described in Year Books Nos. 40 (pp. 89-91) and 41 (pp. 61-63). The magnet-system is ready for continued operation, as tests showed no difficulties

in the generator, magnet, or control. The main vacuum-system and its water-cooling arrangements were completed and tested. The control-system and wiring, with the exception of the radio-frequency circuits (see below), were finished and are ready for operation. All power-supplies are installed, but high humidity during the summer prevented exhaustive tests; the preliminary tests, however, show no reason to expect trouble providing suitable control of humidity for the entire equipment is installed. The radio-frequency system was well under way on June 30, 1943, and the exciter-component had been installed and tested. Completion of the system has been delayed because of slow delivery of the Lenoxite insulators for the 30-kilowatt power-amplifier tubes.

#### MISCELLANEOUS

It was necessary to forego the proposed Annual Conference on Theoretical Physics of 1943, which would have been the ninth in the series at Washington, because of limitations of time and travel.

Full-time occupation of the few men available in completing the cyclotron prohibited preparation of any manuscripts on work already done.

## FIELD-WORK AND REDUCTIONS

## LAND MAGNETIC SURVEY

Some final revisions and additions of new material were made by Wallis and Green for the next volume in the series of Researches of the Department of Terrestrial Magnetism, on "Land magnetic survey, observations, 1927-1940," before preparation of the master-copy for offset printing. The revisions particularly concerned the best possible corrections on standard for instruments, using more complete results of intercomparisons only recently made available. Because of the urgent requests for the data from many organizations actively engaged in the prosecution of the war, both preliminary and final values of geographical positions, magnetic elements, and maps were supplied various public and private institutions.

The compilations for construction of new isoporic charts of the Earth for all components for epochs 1912.5, 1932.5, and 1942.5 were continued. Present grave uncertainties in geomagnetic charts for various regions arise largely from the lack of adequate estimates of secular change. The new isoporic charts, supplemented by those of Fisk for 1922.5, will give a firmer foundation on which more accurate charts of the future can be based.

The study of the adjustment of geomagnetic charts to mutual consistency in all components was continued, including improved methods for practical interpolation in their construction.

A magnetic chart of vertical intensity for epoch 1940 was prepared and was adopted for use by the United States Hydrographic Office and the British Admiralty.

Tables to correct field-observations for geomagnetic variation in annual mean values with sunspot-cycle, annual variation, post-perturbation, and solar daily variation were compiled for all days during 1905

through 1942. Corresponding tables for the storm-time variation and disturbance daily variation are in preparation.

The development of new and simple instruments for observations in the field was continued.

Instruments were loaned to six observatories for cooperative programs of measurement. Instruments were also loaned for magnetic surveys in South America, South Australia, Northern Australia, New Zealand, British East Africa, and the United States, and to various war agencies. International standards and corrections to field-instruments were maintained in cooperation with the United States Coast and Geodetic Survey, using CIW sine-galvanometer 1 and CIW Schulze earth-inductor 48 at the Survey's Cheltenham Magnetic Observatory.

## FIELD-OPERATIONS AND COOPERATIVE SURVEYS

*Africa.* CIW magnetometer and inductor 13 remained on loan to Dr. A. Walter, Director of the British East African Meteorological Service. Observations included monthly determinations of the magnetic elements at Kabete and reoccupations of established stations.

Dr. A. Ogg, of the Magnetic Branch of the Trigonometrical Survey of the Union of South Africa, continued active cooperative measurements using CIW magnetometer-inductor 17.

G. Heinrichs, of Elisabethville Magnetic Observatory, Belgian Congo, communicated magnetic charts and results of observations in the field.

*Australia.* The Department of Supply and Development at Canberra, through its Aerial, Geological and Geophysical Survey of Northern Australia, continued work using CIW magnetometer-inductor 18. Chief Geologist

J. M. Rayner completed new isogonic and isoporic charts of Australasia, based on the results of new measurements and others for earlier years by the Department of Terrestrial Magnetism. Observer-in-Charge W. C. Parkinson at Watheroo Magnetic Observatory cooperated with the Australian authorities in preparing similar charts of recent epoch for Australia.

Astronomer G. F. Dodwell, of the Adelaide Observatory, continued to use CIW magnetometer 6 and CIW dip-circle 226, for which new dip-needles were supplied by the Department of Terrestrial Magnetism.

*New Zealand.* CIW magnetometer-inductor 27 remained on loan to the New Zealand Magnetic Survey of the New Zealand Depart-

ment of Scientific and Industrial Research. Director H. F. Baird reported on October 1, 1942 that 90 stations had been occupied (48 in North Island and 42 in South Island) and that 18 more were planned (6 in North Island and 12 in South Island).

*North, Central, and South America.* Magnetometer-inductors 26 and 28 were loaned to the United States Coast and Geodetic Survey for use in South America, through arrangement with the Department of State, in continuance of previous surveys in the Western Hemisphere.

Loan of equipment to war organizations for field-surveys was also made, and included standardization of instruments and training of observers.

### OBSERVATORY-WORK

Johnston continued in charge of the Section of Observatory-Work. The magnetic reductions and compilations for Watheroo, Huancayo, and College magnetic observatories were maintained current with the assistance of Scott and Miss Balsam. McNish and Torreson were engaged wholly on war research throughout the year. Wait continued discussions of the atmospheric-electric data. The members of staff in residence at the observatories are mentioned in their respective reports.

Continuous records were obtained at Watheroo and Huancayo of the magnetic elements, of atmospheric potential-gradient, and of heights of the ionosphere (by both multifrequency and fixed-frequency transmissions); daily meteorological observations and spectrohelioscopic observations were made (for periods assigned by the International Astronomical Union, but only partially at Watheroo because of other work). The three-component seismograph and precision cosmic-ray meter were continued in operation at Huancayo. The magnetic, auroral, and ionospheric programs were maintained at College.

The usual analyses of the data were

augmented by weekly summaries of magnetic and ionospheric data, predicted values of maximum usable frequencies for various distances, and current forecasts of ionospheric conditions likely to affect radio communication.

The final reductions of the magnetic observations at Watheroo and Huancayo were completed for 1941 and 1942. The hourly values at Huancayo were used to reduce to epoch the results for many magnetic stations obtained in South America by the United States Coast and Geodetic Survey. The preliminary values of the magnetic elements for all days of these years are shown in table 1.

The cooperative program of reporting the international geomagnetic three-hour-range index, *K*, was continued. The Department also functioned as the receiving, compiling, and distributing agency for this measure of magnetic activity, based on reports so far received from 27, 23, and 21 observatories for 1940, 1941, and 1942, respectively.

Weekly reports of indices from the seven American-operated observatories were maintained. Four additional sta-

tions are currently reporting: College, Alaska, through the assistance of the Signal Corps of the United States Army; Toolangi, Victoria, Australia, by the Australian Radio Research Board, through the Royal Australian Air Force; Godhavn and Ivigtut, Greenland, by permission of the Danish Minister, under the direction of the Governor of Greenland, through the Department of State of the United States

at the Department by utilizing all available data on geomagnetic activity, namely, international character-figure,  $C$ ; daily index,  $B$ , based on the  $K$ -indices from 7 American-operated observatories (normalized to represent world-wide conditions with allowance for the nonlinearity of the  $K$ -scales); and averages of the eight daily indices,  $K_M$ , for all available observatories. The selection permits current reduction of

TABLE 1

ANNUAL VALUES OF THE MAGNETIC ELEMENTS AT THE WATHEROO AND HUANCAYO MAGNETIC OBSERVATORIES AS BASED ON MAGNETOGRAMS FOR ALL DAYS, 1941 AND 1942

YEAR	DECLINATION, <i>D</i>	INCLINATION, <i>I</i>	INTENSITY-COMPONENTS					LOCAL MAGNETIC CONSTANT, <i>G</i>
			Horizontal, <i>H</i> ( $\gamma$ )	Total, <i>F</i> ( $\gamma$ )	North-south, <i>X</i> ( $\gamma$ )	East-west, <i>Y</i> ( $\gamma$ )	Vertical, <i>Z</i> ( $\gamma$ )	
WATHEROO MAGNETIC OBSERVATORY								
1941.....	3° 12'3 W	64° 25'2 S	24704	57216	24666	—1381	—51608	35723
1942.....	3 08.2 W	64 24.8 S	24731	57263	24694	—1354	—51647	35756
HUANCAYO MAGNETIC OBSERVATORY								
1941.....	6 50.3 E	2 13.6 N	29471	29494	29262	3509	1146	29477
1942.....	6 45.3 E	2 12.5 N	29438	29460	29234	3462	1135	29444

Government and the communication facilities of the United States Army. Fifty-three issues of "Report of geomagnetic activity" (DTMCIW nos. 284 to 336) were prepared and supplied to organizations or individuals whose legitimate needs are compatible with the war emergency.

The selection of the five international quiet and disturbed days for each month had been made through 1941 under the auspices of the International Meteorological Organization and derived from the international magnetic character-figure,  $C$ . Because of disturbed world-affairs, the number of contributing observatories had decreased from 59 in 1939 to 33 in 1941. The selection of these days for 1942 was made

magnetic observations from all observatories for quiet and disturbed days.

An examination of the mutual consistencies of successive monthly means in declination at Huancayo during 1922 to 1942 was completed by Scott. Additional information was made available on the effect of the sunspot-cycle on annual changes, an effect for which allowance must be made in the reduction to epoch for magnetic observations in the field.

The compilation of the annual values for the world's magnetic observatories of the elements  $D$ ,  $H$ ,  $Z$ ,  $I$ ,  $X$ ,  $Y$ , and  $F$  for all days was continued by Fleming and Scott. The first installment of the "List of magnetic observatories and thesaurus



of values" in order of geographic latitude from Baie Tichaja ( $80^{\circ}3$  north) to Niemegk ( $52^{\circ}1$  north) was published in June 1943.

Cooperative work in geomagnetism and geoelectricity was continued with various observatories. Our international magnetic standards were maintained at the Cheltenham Magnetic Observatory, and the programs in atmospheric electricity and earth-currents (until early 1943) were continued at Tucson Magnetic Observatory; these observatories are operated by the United States Coast and Geodetic Survey. The magnetic observatory at Ivigtut (Greenland), established in 1941, began operation in 1943, and special equipment designed and constructed by the Department to record short-period fluctuations of the Earth's field was delivered and is now operating.

#### OPERATIONS AT OBSERVATORIES

*Watheroo Magnetic Observatory, Watheroo, Western Australia.* The Watheroo Magnetic Observatory is situated in latitude  $30^{\circ}19'1$  south and longitude  $115^{\circ}52'6$  east of Greenwich, 244 meters (800 feet) above sea-level.

The Eschenhagen and la Cour magnetographs were in continuous operation. Weekly determinations of the values of the base-lines for the three elements were made. Monthly determinations of the scale-value of the horizontal-intensity and vertical-intensity variometers were made by magnetic and electric methods. Scale-values of the Eschenhagen vertical-intensity variometer were also determined daily by the electrical method. The monthly scale-values for 1942 for both magnetographs are shown in table 2.

The preliminary values for the annual changes in the magnetic elements from 1941.5 to 1942.5 deduced from the magnetograms for all days, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as

positive, are: declination,  $+4'1$ ; horizontal intensity,  $+27$  gammas; vertical intensity,  $-39$  gammas; inclination,  $+0'4$  (see table 1).

Three-hourly *K*-indices of magnetic character were assigned and transmitted weekly

TABLE 2

SCALE-VALUES OF MAGNETOGRAPHS, WATHEROO  
MAGNETIC OBSERVATORY, 1942

MONTH	SCALE-VALUES IN $\gamma/\text{MM}$			
	ESCHENHAGEN		LA COUR	
	<i>H</i> (reduced to base-line)	<i>Z</i> (means of daily values)	<i>H</i>	<i>Z</i>
January...	2.39	3.20	4.85	3.38
February..	2.40	3.28	4.54	2.87
March.....	2.39	3.27	4.47	3.00
April.....	2.40	3.23	4.38	3.12
May.....	2.40	3.28	4.34	3.43
June.....	2.42	3.10	4.54	3.90
July.....	2.41	3.21	4.72	4.26
August....	2.41	3.11	4.71	4.08
September..	2.39	3.04	4.57	3.75
October....	2.42	3.07	4.57	3.57
November..	2.40	3.17	4.59	3.66
December..	2.42	3.26	4.59	3.21

TABLE 3

DETAILS OF MAGNETIC DISTURBANCES RECORDED  
AT THE WATHEROO MAGNETIC OBSERVATORY DURING 1942

DATE	RANGES		
	<i>H</i> ( $\gamma$ )	<i>D</i> ( $'$ )	<i>Z</i> ( $\gamma$ )
March 1-2.....	212	31	257
October 28-31.....	112	18	115

to Washington. Descriptions of the principal magnetic disturbances during 1942 were prepared; table 3 gives the essential details of these disturbances.

Magnetic data, especially values of magnetic declination and secular variation, were

supplied on request to Australian and United States military units.

The recording of earth-potentials over the system of electrodes, described in previous reports, was continued and compilation of data maintained practically current. Electrode-resistance and line-insulation tests and current plotting of the reduced values indicate satisfactory performance. Calibrations of the recorder were made weekly through 1942 and monthly thereafter.

turbances were supplied until October 1942 to the Department of Air, and thereafter, in accordance with a conference of ionospheric workers in Sydney (at which W. D. Parkinson represented the Observatory) daily reports were sent to Mount Stromlo through the Department of Air. Warnings of approaching ionospheric disturbances were sent to the Department of Air as heretofore. The computation of predicted monthly curves was taken over in October 1942 by the Radio Re-

TABLE 4

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS, WATHEROO MAGNETIC OBSERVATORY, 1942

MONTH	POTENTIAL-GRADIENT			AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU				
	No. selected days	Reduction-factor	Value (v/m)	No. selected days	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+ / \lambda_-)$
January.....	23	1.10	87.4	26	1.64	1.62	3.26	1.01
February.....	12	....	77.6	17	1.80	1.65	3.45	1.09
March.....	18	....	76.1	20	1.70	1.42	3.12	1.20
April.....	21	....	70.2	23	2.08	1.89	3.97	1.10
May.....	21	1.09	66.2	25	2.38	1.88	4.26	1.27
June.....	14	....	70.6	10	2.23	1.66	3.89	1.34
July.....	19	....	74.4	26	2.28	1.80	4.08	1.27
August.....	12	....	88.3	20	2.11	1.68	3.79	1.26
September.....	17	....	82.5	18	1.93	1.50	3.43	1.29
October.....	14	....	89.0	18	1.73	1.37	3.10	1.26
November.....	19	....	85.5	15	1.54	1.39	2.93	1.11
December.....	10	....	100.5	13	1.48	1.37	2.85	1.08
Totals and means....	200	1.10	80.7	231	1.91	1.60	3.51	1.19

Air-potentials were continuously measured by the potential-gradient automatic recorder. The mean of two reduction-factor observations, 1.10, agreed with the factor adopted last year. Weekly calibrations of the electrometer were made. Positive and negative air-conductivities were continuously recorded and weekly calibrations made. Preliminary mean values of the atmospheric-electric elements are shown in table 4.

Scalings and reductions of the automatic multifrequency ionospheric records, except during brief interruptions, were maintained current. Weekly reports of ionospheric dis-

search Board. Complete summaries and copies of tabulations were supplied monthly to the Radio Propagation Committee of Australia. On and after October 1, 1942, the "upper" heights of the  $F_1$ - and  $F_2$ -layers were scaled at hourly intervals, at the request of the Radio Propagation Committee, and on and after February 1, 1943, hourly scalings were made of the "maximum usable frequency" for a path of 3500 km.

Regular watches were kept with the Hale spectroheliograph for solar disturbances, in accordance with the international scheme, until August 1942, when they were discon-

tinued, because of shortage of personnel, except for occasional scannings of the Sun's disk.

Regular observations of meteorological phenomena were continued throughout the year and the automatic recording instruments were maintained in operation. The thrice-daily coded reports on weather, as heretofore, were sent to the forecasting stations at Perth and Geraldton. Only essential control-observations and reductions were made, and most of the scalings had to be deferred.

TABLE 5

RAINFALL AT WATHEROO MAGNETIC OBSERVATORY  
DURING 1942

Month	Monthly total (in.)	No. days	Average for 25 years (in.)
January.....	0.46	4	0.34
February.....	0.00	0	0.53
March.....	1.83	7	1.04
April.....	0.80	6	0.92
May.....	3.12	11	2.21
June.....	2.74	18	3.38
July.....	2.08	10	2.92
August.....	2.06	21	2.20
September.....	1.34	13	1.27
October.....	0.51	9	0.83
November.....	0.03	1	0.32
December.....	0.61	3	0.39
Totals.....	15.58	103	16.35

Table 5 shows the monthly rainfall at the Observatory during 1942. The data obtained with the Friez anemograph were not good because of faults which have developed in the float chamber; replacement has not yet been received to put the recorder in first-class condition.

W. C. Parkinson has continued as Observer-in-Charge. Observer Norman left the Observatory on October 1, 1942. W. D. Parkinson continued as part-time Junior Observer, the remainder of his time being occupied with work for the Department of Air. Because of the greatly reduced staff and the increase

in work essential for defense purposes, the Royal Australian Air Board detailed observers and other assistants to the Observatory. A mechanic and assistant mechanic were regularly employed.

Grateful acknowledgment is made of the valuable assistance rendered to the Observatory during the past year by the following departments of the Australian government and individuals: the Department of Trade and Customs for continued favorable action in regard to imported equipment and supplies; the Directorate of Signals of the Department of Air for transmission of magnetic and other data through their radio channels, for facilities for the safe delivery of records from the Observatory to Washington, and for cooperation in personnel matters; to Lieutenant-Colonel West, CSO of the Line of Communications, Western Australia Area Signals, and Sir David Rivett, Executive Officer of the Council for Scientific and Industrial Research, for assistance in personnel problems.

The necessary reduction in staff arising from the dearth of manpower has imposed added demands on the personnel to maintain instrumental equipment in first-class order and to keep essential work current. All have cheerfully and efficiently cooperated in every way to insure the success of the year's operations.

*Huancayo Magnetic Observatory.* The Huancayo Magnetic Observatory is in latitude  $12^{\circ} 02'7''$  south and longitude  $75^{\circ} 20'4''$  west. It is about  $8\frac{1}{2}$  miles nearly due west of the town of Huancayo in the central valley of the Peruvian Cordillera, and 3350 meters (11,000 feet) above sea-level.

The data collected at the Observatory are obtained, for the most part, from photographic continuously recording automatic apparatus. Time-control marks are registered on the records by electrically operated mechanical or optical devices actuated by a master-clock which is checked and adjusted through radio time-signals.

Two complete three-element Eschenhagen and rapid-run la Cour magnetographs are

operated. A low-sensitivity la Cour horizontal-intensity variometer also records continuously on the Eschenhagen magnetogram. Weekly base-lines were determined for the magnetograms by absolute magnetic observations with magnetometer and earth-inductor. Scale-value determinations were regularly made by the Helmholtz-coil method. Mean monthly scale-values for the magnetic recorders are given in table 6. Orientation-tests and adjustments for the Eschenhagen magnetograph were made in April and May

the instruments were made weekly and the reduction-factor for the potential-gradient was determined quarterly by comparisons with potentials measured on the standardization-plot near by. The preliminary monthly mean values of the atmospheric-electric results for the year 1942 are given in table 7. Condensation-nuclei counts were made daily at 08<sup>h</sup>, 75° west meridian time.

Earth-current potentials were recorded continuously by a Leeds and Northrup recording potentiometer for two separate systems

TABLE 6

SCALE-VALUES OF MAGNETOGRAPHS, HUANCAYO MAGNETIC OBSERVATORY, 1942

MONTH	ESCHENHAGEN			LA COUR	
	$D$ ( $\gamma$ /mm)	$H$ (reduced to base- line) ( $\gamma$ /mm)	$Z$ (means of daily values) ( $\gamma$ /mm)	$H$ ( $\gamma$ /mm)	$Z$ ( $\gamma$ /mm)
January.....	0.992	2.00	4.60	6.24	4.67
February.....	0.990	2.00	4.48	6.19	4.65
March.....	0.990	1.97	4.44	5.96	4.66
April.....	0.988	1.98	4.51	6.19	4.67
May.....	0.992	1.97	4.51	6.34	4.70
June.....	0.986	1.98	4.35	6.23	4.69
July.....	0.992	2.00	4.41	6.10	4.70
August.....	0.986	1.99	4.39	6.76	8.04
September.....	0.989	2.02	4.38	6.24	7.03
October.....	0.995	2.00	4.35	6.35	7.11
November.....	0.986	2.00	4.25	6.17	7.52
December.....	0.994	2.00	4.09	6.02	7.35

1943. Monthly reports of all important magnetic storms and disturbances were made.

The preliminary values for the annual changes in the magnetic elements from 1941.5 to 1942.5 deduced from the magnetograms for all days, referring the elements to the north-seeking end of the needle and reckoning east declination and north inclination as positive, are: declination,  $-5^{\circ}0'$ ; horizontal intensity,  $-33$  gammas; vertical intensity,  $-11$  gammas; inclination,  $-1^{\circ}1'$  (see table 1).

The conductivity of the air (positive and negative) and air-potentials were recorded continuously. Scale-value determinations for

of north-south and east-west pairs of ground-electrodes.

Reflections from the ionosphere were continuously recorded both on fixed frequency of 4800 kc/sec and by the multifrequency ionospheric recorder. Daily control-observations and monthly calibrations were made.

As heretofore, meteorological observations were made daily at 08<sup>h</sup>, 75° west meridian time, and continuous automatic records were made of barometric pressure, air-temperature, humidity, velocity and direction of wind, and hours of sunshine. The rainfall was measured daily; the total for the year from July

1, 1942 to June 30, 1943 was 28.39 inches, slightly lower than the 21-year average of 28.88 inches. Temperatures during the year were: maximum, 24°0 C; minimum, -6°0 C; highest monthly mean maximum, 21°02 C in November; lowest monthly mean minimum, -0°49 C in July 1942.

The cosmic-ray meter, CIW model C no. 2, recorded continuously; weekly controls were made by checking high-potential balance and electrometer-zeros.

and monthly meteorological tabulations were forwarded regularly to the Instituto Nacional de Meteorología e Hidrología (recently changed to Dirección General de Comunicaciones y Meteorología Aeronáutica) and to the Centro Geográfico Departamental de Junín.

Paul G. Ledig, Observer-in-Charge, and Observers Mark W. Jones, Albert A. Giesecke, Jr., and Edwin J. Chernosky continued at the Observatory. The three Peruvian clerical as-

TABLE 7

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS, HUANCAYO MAGNETIC OBSERVATORY, 1942

MONTH	NO. SELECTED DAYS	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU			
		Reduction- factor	Value (v/m)	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+ / \lambda_-)$
January .....	2	....	54.8	3.84	3.80	7.64	1.01
February .....	1	1.17	54.7	3.22	3.00	6.22	1.07
March .....	1	....	57.9	3.45	3.50	6.95	0.99
April .....	8	....	47.6	3.48	3.50	6.98	0.99
May .....	15	1.19	51.4	3.54	3.72	7.26	0.95
June .....	14	....	49.4	4.37	4.68	9.05	0.93
July .....	15	....	51.4	3.78	4.02	7.80	0.94
August .....	6	1.17	47.2	4.30	4.50	8.80	0.96
September .....	7	....	49.8	3.82	3.98	7.80	0.96
October .....	4	....	45.4	4.20	4.26	8.46	0.99
November .....	4	....	42.0	4.28	4.23	8.51	1.01
December .....	3	....	47.4	4.55	4.60	9.15	0.99
Totals and means .....	.80	1.18	49.9	3.90	3.98	7.88	0.98

The two Wenner horizontal-component and the Benioff vertical-component seismometers operated satisfactorily. Analyses were made of all important seismic disturbances, and a total of 46 were reported in the international seismic code with the weekly broadcast of magnetic activity.

Daily observations to detect solar activity were made with the Hale spectroheliograph whenever weather permitted, and monthly reports were prepared.

Magnetic and meteorological data were supplied to interested persons and institutions,

assistants, T. Astete, A. Macha, and V. Murga, assisted in preparation of data and various items of instrumental maintenance. The loyal cooperation and enthusiasm of these members of the staff have made possible the successful completion of another year of our extended program of geophysical research.

Grateful acknowledgment is made for the generous assistance of the American Embassy in obtaining free entry for shipments of supplies for the Observatory, and to the Peruvian government for granting this privilege. Our Peruvian friends, including those in official

positions, continued active interest in the work and gave valuable help.

*College Observatory, Alaska.* The College Observatory is located at the University of Alaska in the zone of maximum auroral activity, about 5 miles by road west of Fairbanks, in latitude  $64^{\circ} 51'4''$  north, longitude  $147^{\circ} 49'3''$  west, at about 381 meters (1250 feet) above sea-level.

Ionospheric records with the multifrequency equipment, similar to that at Watheroo and Huancayo, were continued. The resulting compilations of data are especially valuable as regards unique ionospheric conditions prevalent in high latitudes. Weekly summaries were transmitted through the United States Army Signal Corps.

Special studies and reports relating to ionospheric problems were made by the staff of the Observatory in cooperation with the United States Army, the Civil Aeronautics Administration, and the Federal Communications Commission station at Fairbanks. Among these were: communications predictions for the Alaskan Area; direction-finder errors; comparison of actual with theoretical values of maximum usable frequencies; relation between doubly refracted magneto-ionic components in high latitudes; comparison of methods for deduction of maximum usable frequencies from vertical-incidence ionospheric measurements; analytical examination of relative sporadic *E*-layer ionization to both magnetic and auroral activity; theoretical examination of lateral deviations of radio waves caused by systematic tilting of the ionosphere; ionospheric measurements during the partial solar eclipse of February 4, 1943; and study of high-frequency communications circuits in Alaska.

Charts were prepared showing the systematic diurnal and seasonal changes in transmission characteristics of the ionosphere. In general terms these characteristics may be described as follows: In summer the *F*-region ionization attains a broad maximum near noon and decreases at night to a not greatly lower minimum. In winter the *F*-region ionization attains a high maximum, sharply

peaked at midday, and remains quite low during the night. Sporadic *E*-region blanketing is the rule at night, and the high incidence and variability of intense *E*-region ionization during the night hours are the outstanding observed phenomena of importance to propagation of radio waves in high latitudes. Radio "blackouts" characterized by the cessation of all echoes on frequencies up to 16 Mc/sec continued to be of great frequency and long duration. A comparison of current *F*-region critical frequencies with those observed during corresponding months of the previous year indicated a current secular decrease in ionization of about 30 per cent per year. The parallel decrease in sunspot-numbers was about 40 per cent.

The ionospheric data as compiled are not entirely homogeneous because of several factors, as follows: (1) Separation of the *F*-layer does not occur in midwinter, so that *F*<sub>1</sub>-data cannot be ascertained for a high percentage of the time; (2) during a number of hours in midday in summer the maximum height of the *F*<sub>2</sub>-region cannot be ascertained because of the proximity of the *F*<sub>1</sub>- and *F*<sub>2</sub>-critical frequencies; (3) sporadic *E*-region blanketing at night and fade-outs during the day often prevent the determination of the quantities. For the sake of uniformity, consideration is given only to those monthly means of hourly values obtained when the data are recorded about 50 per cent or more of the time.

The insensitive la Cour magnetograph was continued in operation during the year July 1, 1942 to June 30, 1943. Scale-values were maintained at 18.2γ/mm for horizontal intensity, 26.5γ/mm for vertical intensity, and 5.2γ/mm for declination. Base-line and scale-value determinations were made at weekly intervals. The preliminary mean values for all days of the year 1942 are: declination,  $+29^{\circ} 52'0''$ ; horizontal intensity, 12582γ; vertical intensity, +55342γ.

A disturbance daily variation with well defined peak at about 11<sup>h</sup>30<sup>m</sup> GMT (shortly before local magnetic midnight) is indicated by the monthly mean ratings of hourly disturb-

ance, or, more roughly, by the three-hour-range indices,  $K$ . As a measure of the "usability" of the ionosphere, the daily sums of the  $K$ -indices provided figures which are perhaps in better accord with observed radio-communication conditions than are indices of disturbance based on the ionospheric records. The daily magnetic indices are closely related to daily sums of hourly minimum frequencies derived from the ionospheric data, this quantity constituting a measure of absorption of energy in the ionosphere. Particularly during night hours, however, intense and variable sporadic  $E$ -region blanketing is a factor affecting the usability of the ionosphere, and this is not necessarily reflected by an increase in the minimum frequencies. The close correlation between the two indices may be attributed to that between the occurrence of high sporadic  $E$ -layer ionization at night and fade-out conditions, with increased absorption of the lower frequencies, during adjacent daylight hours. Association of magnetic and ionospheric disturbances gives added utility to current magnetic records in regions near the auroral zone.

Both photographic and visual auroral observations were continued during the 1942-1943 season. Exposures of the night sky near the zenith at 2.5-minute intervals were made with the automatic camera. Visual observations included hourly estimates of auroral activity, extent, and intensity throughout hours of darkness according to auroral indices from 0 to 9.

Bramhall was Physicist-in-Charge to May 1, 1943, when he transferred the Observatory to Seaton and returned for duty at Washington. Seaton was assisted by observers and others of the temporary staff. The results obtained evidence the efficiency and diligence of the personnel.

Grateful acknowledgment is due President Bunnell and the Regents of the University of Alaska for the large and generous part taken in providing facilities for the Observatory and its operation. Cordial liaison with civil and military authorities, interested in problems of

communication in Alaska, was also a most important factor and stimulus.

#### COOPERATION WITH OTHER OBSERVATORIES

*Cheltenham Magnetic Observatory, United States.* The cooperative program with the Cheltenham Magnetic Observatory of the United States Coast and Geodetic Survey was continued, using CIW instruments for absolute standards in horizontal intensity and inclination. Automatic daily records of cosmic-ray intensity were maintained with the CIW precision cosmic-ray meter, with the assistance of Observer-in-Charge J. Hershberger. Facilities for the standardization of our magnetometers and inductors were furnished.

*Apia Observatory, Western Samoa.* The Department continued cooperation with the Apia Observatory through its Acting Director, H. B. Sapsford. In the geomagnetic program, CIW magnetometer 9 and CIW Schulze earth-inductor 2 were used for absolute observations. The annual magnetic reports for the years 1941 and 1942 are almost complete.

*Tucson Magnetic Observatory, United States.* In cooperation with the United States Coast and Geodetic Survey, complete and continuous registrations of atmospheric potential-gradient, and of positive and negative air-conductivities, were obtained with the assistance of Observer-in-Charge J. H. Nelson, using equipment supplied by the Department. The earth-current program, made possible through the cooperation of the Bell Telephone System, was discontinued early in 1943 (see p. 40). Table 8 summarizes the monthly and annual values of the atmospheric-electric elements as computed by Mrs. G. Dewey and assembled by Sherman. There were no observations of reduction-factor during the year.

*Hermanus Magnetic Observatory, South Africa.* CIW magnetometer-inductor 17 continued in use. Dr. A. Ogg sent  $K$ -indices promptly and reported that the magnetic reductions had been kept current.

*Godhavn Observatory, Greenland.* Because of the war, cooperation was continued in pro-

viding supplies and instrumental replacements for the magnetic program. K. Thiesen, of the Observatory, continued his collaboration with the Cosmic-Ray Committee of the Institution by operating the CIW precision cosmic-ray meter. *K*-indices were communicated weekly from February 1943 through

of Greenland, and with authorization of the Danish Minister at Washington, D. C., Mr. Thiesen spent a short time at Ivigtut to initiate the continuous recording. He installed the CIW specially designed elements in the variometers of the second magnetograph. *K*-indices have been reported weekly since May

TABLE 8

PRELIMINARY MONTHLY MEAN VALUES OF ATMOSPHERIC-ELECTRIC ELEMENTS, TUCSON MAGNETIC OBSERVATORY, 1942

MONTH	POTENTIAL-GRADIENT		AIR-CONDUCTIVITY, UNIT $10^{-4}$ ESU				
	No. selected days	Value (v/m)	All complete days	$\lambda_+$	$\lambda_-$	$(\lambda_+ + \lambda_-)$	$(\lambda_+/\lambda_-)$
January . . . . .	28	69.2	31	1.91	1.75	3.66	1.09
February . . . . .	21	55.0	28	2.15	2.10	4.25	1.02
March . . . . .	21	57.8	29	2.04	2.03	4.07	1.01
April . . . . .	20	47.6	28	2.48	2.33	4.81	1.06
May . . . . .	24	53.0	30	2.55	2.42	4.97	1.05
June . . . . .	23	52.8	28	2.69	2.61	5.30	1.03
July . . . . .	11	49.4	28	2.29	2.08	4.37	1.10
August . . . . .	19	56.3	25	2.56	2.31	4.87	1.11
September . . . . .	22	46.6	27	2.61	2.40	5.01	1.09
October . . . . .	20	49.7	29	2.53	2.35	4.88	1.08
November . . . . .	24	54.0	30	2.55	2.35	4.90	1.09
December . . . . .	26	72.0	30	2.18	1.97	4.15	1.11
Totals and means . . . . .	259	55.3	343	2.38	2.22	4.60	1.07

the United States Department of State. Current tabulations of hourly values for all magnetic elements were supplied.

*Ivigtut Magnetic Observatory, Greenland.* During the summer of 1942 a magnetograph was installed by K. Thiesen. It was operated intermittently during the summer while a magnetic survey of the area was in progress. Arrangements were made by the Department early in May 1943 with S. O. Corp, Manager of the Ivigtut Cryolite Mines, who generously offered to operate the Observatory continuously. At the direction of Governor E. Brun

29, 1943 through the cooperation of the United States Army Communication Services.

*Christchurch Observatory, New Zealand.* Director H. F. Baird continued operation of the CIW precision cosmic-ray meter. *K*-indices were regularly supplied.

*Royal Alfred Observatory, Mauritius.* CIW marine-inductor 4 was used for the control of the vertical-intensity records.

*Teoloyucan Observatory, Mexico.* Dr. J. Gallo, Director of the National Astronomical Observatory of Mexico, continued operation of the CIW precision cosmic-ray meter.



## PUBLICATIONS ON THE "CARNEGIE" DATA

Six quarto volumes of the series under the general title "Scientific Results of Cruise VII of the *Carnegie* during 1928-1929, under command of Captain J. P. Ault" were published by the Institution. These were: "Biology—I: The copepods of the plankton gathered during the last cruise of the *Carnegie*" (237 pages), by Charles B. Wilson; "Biology—II: The oceanic Tintinnoida of the plankton gathered during the last cruise of the *Carnegie*" (163 pages), by Arthur Shackleton Campbell; "Biology—III: Studies in the morphology, taxonomy, and ecology of the Peridiniales" (129 pages), by Herbert W. Graham; "Biology—IV: Biological results of the last cruise of the *Carnegie*" (92 pages), a series of short reports by Herbert W. Graham, William Albert Setchell, Aaron L. Treadwell, W. M. Tattersall, James O. Maloney, Harry G. Barber, Alexander Wetmore, M. W. de Laubenfels, Austin H. Clark, E. A. Chapin, Hoyt S. Hopkins, and Doris M. Cochran; "Meteorology—I: Meteorological results of cruise VII of the *Carnegie*, 1928-1929" (168 pages), by Woodrow C. Jacobs and Katherine B. Clarke; and "Meteorology—II: Upper-wind observations and results obtained on cruise VII of the *Carnegie*" (94 pages), by Andrew Thomson.

The master-copy and diagrams of re-

sults in physical oceanography were half completed by June 30, 1943. This volume is being prepared in two parts: "Oceanography—I-A" (150 pages), by J. A. Fleming, H. U. Sverdrup, and F. M. Soule; and "Oceanography—I-B" (300 pages), by J. A. Fleming, C. C. Ennis, S. L. Stuart, and W. C. Hendrix. The first part relates to outline of cruise, descriptions of equipment, and discussions of results in physical oceanography. The second part includes the extended tables and some 254 graphs of observed and reduced data.

The master-copy for "Physical Oceanography—II: Marine bottom samples collected in the Pacific Ocean on the last cruise of the *Carnegie*" (190 pages), by Roger Randall Revelle, has been completed. This volume includes also "Radium-content of ocean-bottom sediments," by Charles Snowden Piggot.

Other volumes in the series awaiting publication are "Biology—V," by Herbert W. Graham, and "Chemistry—I," by Herbert W. Graham, E. G. Moberg, and J. P. Ault.

The laborious task of preparing final master-copies for offset production from the manuscripts is being performed by Miss Todd, with the assistance of Hendrix in connection with final arrangement of graphs and other illustrations.

## INSTRUMENT-SHOP

The numerous obligations for the design and construction of special models and apparatus for war problems, under nine contracts with the Army, Navy, and Office of Scientific Research and Development, were effectively met in the Instrument-Shop by Foreman Steiner and the men of the regular and temporary staffs under

his direction. The application and overtime given by all have been most important in the success attained.

In addition to the war work, which took 70 per cent of the time available, excellent progress was made in the cyclotron installation, now nearing mechanical completion. The urgent necessary maintenance of

buildings, laboratory facilities, equipment for and shipment to the observatories, and

grounds, as well as provision for the increased personnel, was maintained.

### MISCELLANEOUS ACTIVITIES

Members of the staff took part in scientific meetings and organizations as officers and members and in special committees. Contacts were maintained with geophysicists in the United States and abroad—so far as was possible under existing conditions—through cooperation with the American Geophysical Union, which also represents the National Research Council in the International Union of Geodesy and Geophysics. The participation of the scientific personnel in matters relating to the war effort, through the bureaus of the United States Army and Navy and the Office of Scientific Research and Development, have also required conferences with cooperating observatories and organizations in various parts of the United States and Canada.

*Library.* There was continued rapid decrease in the flow of publications from European countries, other than Great Britain, and in the number of papers on researches of interest to the Department. As a result of this and the absorption of American men of science into war-research work, which further lessened the publication of geophysical results in America, there were only 394 accessions during the report-year as against 456 last year, bringing the total number of accessioned books and pamphlets to 27,053. All articles in current periodicals, reprints, and other pamphlets received which related to researches of interest to the Department were catalogued.

The voluminous Wilkes collection of unpublished manuscripts of the United States Exploring Expedition of 1838–1842 at the Library of Congress was examined, and a

compilation of the values of the observed declination was prepared. This examination was facilitated by Dr. St. George Sioussat, Chief of the Division of Manuscripts of the Library of Congress, and his assistants. The magnetic data on file at the United States Hydrographic Office were also examined. The greater part of the many observations of declination which are known to have been obtained, and which were to have been published in the Expedition's volume on "Physics," has not yet been found.

The modern student of geomagnetism is rightly concerned with practical and theoretical studies and has little time to investigate the historical development of the science. Still, such study is well worth while, for it adds much interest to the subject and reveals the long and tedious progress through many centuries. To the regular worker, an exhaustive study of the subject is practically impossible because of the inaccessibility of the sources and the diversity and difficulties of the languages in which the early contributions to the science were written. In order that these important documents might be available to investigators, Librarian Harradon undertook the task of translating some of them and of adding information regarding their authors and background. Three of these translations with notes were published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity* (see bibliography). A paper on this matter was presented before the Section of Terrestrial Magnetism and Electricity of the American Geophysical Union on April 23, 1943.

The Librarian continued as coeditor of

the *Journal of Terrestrial Magnetism and Atmospheric Electricity*, giving attention particularly to foreign contributions, preparation of notes, reviews of books and reports, and annotated bibliographies of recent publications on geomagnetism, geoelectricity, and cosmic relations. His list of published papers by members of the Department up to December 31, 1942 showed a total of 2217. Reprints of these papers were distributed to interested persons and institutions. Because of the war, distribution of reprints to foreign addresses was somewhat interrupted. Harradon revised the manuscripts by R. G. Fitzsimmons and M. Wiener on the magnetic and auroral results obtained by the United States Antarctic Expedition of 1939-1941, which are being published by the United States Department of the Interior.

The facilities of the library, as in previous years, were made available to research workers and students from educational institutions and government bureaus and, in particular, to specialists engaged on war problems. The practice of inter-library loans was continued, and reciprocal and cordial relations were maintained, particularly with the Library of Congress. With the latter, the Department cooperated in various ways, particularly in furnishing its list of holdings of Axis-controlled scientific journals since 1939 to aid in the compilation of the catalogue of such journals available in libraries throughout the United States.

Dove continued as Secretary to the Di-

rector and in charge of the general correspondence files of the Department and the storage and distribution of reprints. He also typed a large number of reports and manuscripts.

*Office administration.* Most of the regular time and much overtime was required in correspondence, placing of orders, priority procedure for materials and travel, accounting, and matters concerned with personnel, in connection with the war work for the government under contracts with the Office of Scientific Research and Development, the Navy Department, and the Signal Corps.

The responsibilities of the greatly increased demands of office and personnel were effectively met by M. B. Smith, administrative assistant, with the cooperation of Moats, Miss Gottshall, Miss Dermody, and Dove of the regular staff, and the many temporary members assigned to the Section of Administration and Accounting.

Capello, secretary and property-clerk, had charge of shipments and inventory, maintained detailed monthly statements of time and costs of work in the shop, and prepared manuscripts. The drawings, charts, and illustrations for publications and reports were prepared by Hendrix. He and J. W. Green also handled the photographic work. The records received from the observatories and field were arranged and filed by Miss Balsam, who with Capello kept current the cataloguing of photographic films and index-albums of prints.

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## SPECIAL PUBLICATIONS

Scientific results of cruise VII of the Carnegie during 1928-1929 under command of Captain J. P. Ault:

*Biology—I.* The copepods of the plankton gathered during the last cruise of the *Carnegie*. By C. B. Wilson. Carnegie Inst. Wash. Pub. 536. v + 237 pp., 136 figs. (1942).

*Biology—II.* The oceanic Tintinnina of the plankton gathered during the last cruise of the *Carnegie*. By A. S. Campbell. Carnegie Inst. Wash. Pub. 537. v + 163 pp., 1 pl., 128 figs. (1942).

*Biology—III.* Studies in the morphology, taxonomy, and ecology of the Peridiniales. By H. W. Graham. Carnegie Inst. Wash. Pub. 542. vii + 129 pp., 1 pl., 67 figs. (1942).

*Meteorology—I.* Meteorological results of cruise VII of the *Carnegie* 1928-1929. By W. C. Jacobs and K. B. Clarke. Carnegie Inst. Wash. Pub. 544. v + 168 pp., 62 figs. (1943).

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## SPECIAL PROJECTS: TERRESTRIAL SCIENCES

COMMITTEE ON COORDINATION OF COSMIC-RAY INVESTIGATIONS. *Progress report for the period July 1942 to June 1943.* (For previous reports<sup>1</sup> see Year Books Nos. 32-41.)

Activities in cosmic-ray research were further reduced during the year ending June 30, 1943, because of assignment of interested personnel to war-research problems. Some progress was made, nevertheless, as is evidenced by the appended reports of investigators with whom the Carnegie Institution of Washington co-operated.

There is only a remote possibility that research on cosmic rays may find application to wartime problems. It is essential, nevertheless, in view of past experience, that so far as possible continuity of permanent records with cosmic-ray meters be maintained for future theoretical and statistical investigation. Under the general supervision of the Department of Terrestrial Magnetism the cosmic-ray meters at Cheltenham, Huancayo, Teoloyucan, Christchurch, and Godhavn were kept in operation by the collaborating agencies. For stations abroad the necessary arrangements were effected despite difficulties of obtaining materials, supplies, and shipping facilities.

No work was reported by Professor M. S. Vallarta at the Massachusetts Institute of Technology or by Professor R. B. Brode at the University of California, because of their assignment to urgent war problems.

The investigations of Professor A. H. Compton's group at the University of Chicago were continued on a limited scale. Professor Compton could not spare time to prepare a formal report. His program includes investigations of time- and height-variations of cosmic rays, composition and

intensity of cosmic rays, production of secondary radiation, and properties of the mesotron. Several brief abstracts on the investigations have appeared in *Physical Review*; these relate to evaluation of the lifetime of the mesotron, theory of atmospheric cosmic-ray showers, nature of primary radiation, slow mesotrons in the stratosphere, and reduction of mesotrons and measurements of cascade showers produced by ionizing and non-ionizing radiation.

S. E. Forbush, on leave of absence during the entire year on a war-research assignment, could give only the time necessary to consider details of maintenance of the cosmic-ray meters. Miss Isabelle Lange, despite the necessity of giving the greater part of her time to compilations concerned with war research, continued the necessary control checks of data received. The magnetic-storm effect of March 1, 1942, reported on last year, was further confirmed by data received since that report from Godhavn and Christchurch. This was the first definite case of a latitude-effect in cosmic-ray changes occurring during magnetic storms, and was the first recorded case of large sudden simultaneous increases in cosmic-ray intensity at widely separated stations.

Professor Victor F. Hess and associates at Fordham University further confirmed results previously reported on the latitude-effect, and found also a longitude-effect. It was concluded that the magnitude of temperature-coefficients of cosmic-ray intensities depends less on geomagnetic latitude than on the distribution of air-masses in the upper atmosphere. The model-C meter used on the *Santa Ana* was removed

<sup>1</sup> For statement on formation, purposes, and policies of the Committee see Year Book No. 38 (1938-1939), pp. 335-349.



in April 1943 at San Francisco and shipped to Professor Compton at the University of Chicago.

At the Bartol Research Foundation Dr. Thomas H. Johnson and associates completed the high-pressure cloud-chamber for use under pressures as great as 200 atmospheres. Five hundred photographs at a pressure of 110 atmospheres were taken, and a statistical study of these is under way. A statistical analysis of some 40,000 photographs made with the 24-inch cloud-chamber was begun.

At New York University Professor S. A. Korff constructed a large boron trifluoride counter, with which the neutron-intensity at sea-level was studied; this counter showed an improvement in sensitivity by a factor of 7 over previous determinations. Correlations were established between the cosmic rays at sea-level, when corrected for sea-level barometric pressure, and the fluctuations in the pressure at given levels in the upper atmosphere.

Dr. Robert A. Millikan and his associates and students at the California Institute of Technology continued, as far as urgent war-research demands permitted, the study of the origin of cosmic rays on the hypothesis proposed two years ago; confirmatory evidence was found. Improved resolution of the cloud-chamber method of measuring masses of mesotrons and the transformations of energy resulting in their birth and disappearance was obtained. Preliminary measurements were made of the curvature of 135 tracks in a magnetic field of 4500 gauss.

Dr. C. E. Nielsen and Dr. Wilson M. Powell at the University of California found time to determine the maximum values of slow mesotrons through the examination of some 7000 photographs made on Mount Evans at 14,100 feet and 1800 photographs made at Summit Lake

at 12,700 feet (see Year Book No. 41, p. 102).

Grateful acknowledgment is made to the directors and members of organizations which continued their contributions and services to the program; these include the Danish Meteorological Institute, the National Astronomical Observatory of Mexico, the New Zealand Department of Scientific and Industrial Research, and the United States Coast and Geodetic Survey. The Consul-General of Denmark in New York and the United States Coast Guard were most helpful in connection with the forwarding of the necessary supplies for operation and maintenance of the observatory at Godhavn.

W. S. ADAMS

J. A. FLEMING, *Chairman*

F. E. WRIGHT

#### STATISTICAL INVESTIGATIONS OF COSMIC-RAY VARIATIONS

S. E. FORBUSH AND ISABELLE LANGE

*Department of Terrestrial Magnetism,  
Washington, District of Columbia*

*Instruments.* Operation of the Carnegie Institution's precision cosmic-ray meters was continued at the following stations: Cheltenham (Maryland, United States) Magnetic Observatory of the United States Coast and Geodetic Survey, meter C-1, John Hershberger in charge; Huancayo (Peru) Magnetic Observatory of the Department of Terrestrial Magnetism, Carnegie Institution of Washington, meter C-2, P. G. Ledig in charge; National Astronomical Observatory of Mexico at Teoloyucan (D. F., Mexico), meter C-4, Dr. Joaquin Gallo in charge; Amberley Branch of the Christchurch (New Zealand) Magnetic Observatory of the Department of Scientific and Industrial Research, meter C-5, J. W. Beagley in charge; Godhavn (Greenland) Magnetic Observatory of the

Danish Meteorological Institute, meter C-6, K. Thiesen and H. P. Barfod in charge.

*Reduction of data.* Scalings and tabulations of hourly values of cosmic-ray ionization, bursts, and barometric pressure could not be kept current owing to pressure of war work.

*Investigations.* The striking example of the magnetic-storm effect on cosmic data which occurred during the magnetic storm beginning at 7.5<sup>h</sup> GMT March 1, 1942, and which was mentioned in last year's report, has been further confirmed by data subsequently received from Godhavn and Christchurch. In addition to the world-wide decrease which has often been observed in cosmic-ray intensity during the main phase of magnetic storms, the cosmic-ray intensity at Godhavn, Cheltenham, and Christchurch increased suddenly from 6 to 8 per cent simultaneously at about 10<sup>h</sup> GMT, February 28, and again at about 05<sup>h</sup> GMT, March 7, 1942. The cosmic-ray intensity decreased to its previous value in about six or eight hours. These two striking increases were not observed at Huanacayo. This appears to be the first definite case of a latitude-effect in cosmic-ray changes occurring during magnetic storms, and also the first case of large sudden increases in cosmic-ray intensity observed simultaneously at several widely separated stations. These increases are probably the result of the magnetic effect on cosmic-ray trajectories due to eastward-flowing ring-currents, or their magnetic equivalents of the type required to explain the world-wide increase in horizontal magnetic intensity which usually precedes the main phase of magnetic storms.

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#### REPORT ON COSMIC-RAY WORK

VICTOR F. HESS

*Fordham University, New York, N. Y.*

*Studies on cosmic-ray intensities aboard the "Santa Ana" between New York and Chile, by Edward B. Berry and V. F. Hess.* The results of the registrations of cosmic-ray intensities with a model-C meter between New York and Chile from September 1940 to February 1942 were evaluated and published in the *Journal of Terrestrial Magnetism and Atmospheric Electricity* (September 1942). The latitude-effect was 8.3 per cent. A longitude-effect of 1.5 per cent between 75° west and 145° west was also found. The curve of temperature-coefficients was found to be symmetrical about 23° north of the geomagnetic equator, in contrast with a similar curve found by P. S. Gill for the Pacific, which is symmetrical about the geomagnetic equator.

It was concluded that the magnitude of the temperature-coefficient of cosmic-ray intensities depends less on geomagnetic latitude than on the distribution of air-masses in the upper atmosphere. Variations of cosmic-ray intensity during the severe magnetic storm of March 1, 1942 were found, in good agreement with those reported by other observers.

The model-C meter was removed from the *Santa Ana* in April 1943 by Rev. E. B. Berry (of Fordham University) in San Francisco and shipped to Dr. A. H. Compton at the University of Chicago.

*Cosmic-ray studies with dual telescope (1943), by F. A. Benedetto.* Work during the year 1943 has been confined to verification of results previously reported by Hess and Benedetto and by Benedetto, Altmann, and Hess (1942). The dual telescope was taken apart and completely overhauled in the fall of 1942 and observations were taken from January to August

1943. The results were in substantial agreement with the earlier registrations obtained with the same apparatus. These studies indicate that closer correlation is obtained by integration of the daily temperature-versus-pressure plot from the ground up to four-fifths level of the daily atmosphere (about 1010 to 202 mb) than by taking smaller intervals. The daily values of temperature thus obtained are referred to as "mass-temperatures." Previous investigators have calculated the temperature-coefficient of the mesotron-component confining themselves principally to either the temperature at the surface or the temperature prevailing at some particular level of the atmosphere.

Results with mass-temperatures, however, show that both a higher correlation-coefficient ( $r$ ) and a higher value of the temperature-coefficient ( $\alpha$ ) are obtained by using mass-temperatures than by the former methods. It is also indicated that a determination of the proper lifetime value for the mesotron based on the temperature-coefficient should take into consideration the production, absorption, and energy spectrum of the mesotron throughout the atmosphere, and that the simplifying assumption of the mesotron production at a certain "preferred" level instead of continuously throughout the atmosphere should be expanded into a more general treatment involving these distributions. It is hoped that further work along these lines can be undertaken after the war.

Grateful acknowledgment is made to Dr. W. F. G. Swann for making available the facilities of the Bartol Research Foundation in the repair of a number of Geiger-Mueller tubes.

Results obtained during January to August 1943 will appear in an early issue of the *Physical Review*.

*Gish-Hess ionization-meter.* This instru-

ment, to be used with three ionization-vessels of different dimensions, was completed in the summer of 1942 and was studied in its performance by O. H. Gish and K. L. Sherman at the Department of Terrestrial Magnetism before it was taken over by V. F. Hess in August 1942. A report on these studies and on the calibrations was given by Gish and Sherman.

V. F. Hess began experiments in the field with this instrument in the spring of 1943. Experiments on the variations of the total ionization at points in the New York area and experiments over rocks are in progress.

The author wishes to acknowledge the valuable aid of the Director, Assistant Director, and their associates in the Department of Terrestrial Magnetism in his work.

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#### STUDIES OF COSMIC RAYS

THOMAS H. JOHNSON

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Because of war research and war teaching, the projected program of cosmic-ray research had to be sharply curtailed. Nevertheless some progress was made.

The high-pressure cloud-chamber begun in 1941 was completed and put into operation with results that exceeded expectations. This chamber embodied a new design which made it possible to exceed the pressures previously used in large cloud-chambers by a very considerable factor,

and it was constructed for the purpose of increasing the rate of photographing some of the rare cosmic-ray phenomena, such as mesotron-stoppages in the gas and their disintegrations. The present chamber is 12 inches in diameter and is designed to run at a pressure of 200 atmospheres. Under this pressure each track has a 200-fold increase in probability of displaying some interesting feature as compared with tracks taken at normal pressure, and because of the low rate of diffusion of ions at high pressure and the almost negligible turbulence consequential to the low expansion-ratio, the period of sensitivity of this chamber is increased to such an extent that every photograph contains several tracks. Thus the rate of photographing mesotron-stoppages in the gas has been increased from something of the order of one track per annum to one track every day or two. During about one month of operation of the chamber at a pressure of 110 atmospheres, 500 photographs were taken. Some of these have already been reported, but the statistics of the group as a whole is still under study.

The work of the year has also included the analysis of 40,000 photographs taken with a 24-inch cloud-chamber operating at a pressure of about one atmosphere. A report of these statistics is in the course of preparation.

The work has been carried on principally by Ralph P. Shutt, who has been engaged on these studies full time for part of the year and part time during a period of war teaching; and by Dr. Sergio de Benedetti, who was engaged for either full or part time prior to January 1943.

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#### COSMIC-RAY INVESTIGATIONS

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The study of cosmic rays carried out between July 1, 1942 and June 30, 1943, with the aid of funds administered by the Carnegie Institution of Washington, consists of two phases: (1) a determination of the intensity of neutrons produced by the cosmic radiation at sea-level, and (2) the construction of a differential counter-telescope for the purpose of analyzing the correlation between the fluctuations in the cosmic-ray intensity at sea-level and the variables of the meteorology of the upper atmosphere.

*Study of cosmic-ray neutrons at sea-level.* Existing measurements of the cosmic-ray-neutron intensity at sea-level have been unsatisfactory, partly because of the lack of sensitivity of the detecting equipment and partly also since the measurements were not so made as to permit unique rates of production of the neutrons to be determined. In order to obtain measurements satisfactory on these two scores, a large boron trifluoride counter was constructed, 75 cm in effective length and 15 cm in diameter. With this counter the neutron-intensity at sea-level was studied by surrounding it completely with paraffin 30 or more cm thick and then determining the counting-rates of the arrangement with and without shields of cadmium and boron. The counter was of such efficiency that

approximately 11 neutrons per minute were detected—an improvement in sensitivity by a factor of 7 over previous determinations. This arrangement made it possible to determine the rate of production of neutrons by cosmic rays per gram per second in paraffin at sea-level. It is believed that the value obtained in this manner is accurate to about 10 per cent. This will provide a basis for ascertaining the number of neutrons produced at other elevations. The characteristics of very large counters were also studied in this investigation.

*Investigation of the connection between upper-air meteorology and cosmic-ray intensity at sea-level.* It will be recalled that, since the majority of cosmic rays reaching sea-level consist of mesotrons, the number reaching sea-level is determined not only by the loss of energy due to ionization, but also by the numbers which disappear by decay. The amount of decay which a given beam experiences depends on the length of path and on the energy of these particles. There is a complex relation between the ionization-loss and the loss due to decay. In order to analyze the situation, a twin differential cosmic-ray telescope was constructed in which the intensity in a vertical beam could be measured with the various amounts of lead. By subtracting the intensity observed with one amount of lead from that observed with a smaller amount, a definite energy-band in the radiation could be isolated and the fluctuations in this band studied in connection with the meteorological variables obtained from the radiosonde flights. This analysis determines a ratio of mass to lifetime, taking account of the variation in energy along the beam. Correlations were established between the cosmic-ray intensity at sea-level, when corrected for sea-level barometric pressure, and the fluctuations in the pressure at given levels in the upper atmosphere.

Papers entitled "The intensity of neutrons produced by cosmic radiation at sea-level" and "An analysis of mesotron lifetime-to-mass ratio by a differential telescope" and a "Report on cosmic-ray observations on the U. S. Antarctic Expedition" are in preparation for publication.

*Personnel.* Data obtained with the Millikan-Neher cosmic-ray meters were reduced by Ernest K. Smith. Those obtained with the cosmic-ray telescope and the correlations with the meteorological variables were worked out by John White. Messrs. K. and M. Kupferberg and T. Swearingen constructed the twin differential telescope and K. Kupferberg worked out much of the analysis of the results. M. Kupferberg made the measurements of neutron-intensity at sea-level.

#### STUDIES OF COSMIC RAYS

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On account of the practically complete absorption in war activities of all the members of the cosmic-ray group of workers at the California Institute of Technology, no general report on experimental accomplishment in this field from July 1, 1942 to July 1, 1943 can be made. Some time has been found, however, for analyzing the results of experiments made late in 1941 and through April 1942, and for getting the results into proper channels of publication. The summary of the present status of the two large cosmic-ray undertakings is as follows:

*Origin of cosmic rays, by Robert A. Millikan, H. Victor Neher, and William H. Pickering.* The hypothesis proposed as to the origin of cosmic rays is that whereas the evolution of energy by the stars is maintained, as Bethe has recently shown, by the *partial* transformation within the stars of the rest-mass energy of hydrogen

into radiant energy through the building of helium, carbon, and other atoms out of hydrogen and the release through this process of the so-called "packing-fraction" energy, the energy of cosmic rays, on the other hand, is maintained by the *occasional complete* transformation in interstellar space of the rest-mass energy of the atoms of helium, carbon, nitrogen, oxygen, and silicon (and presumably in small amounts of heavier aggregates) into cosmic rays; each such event presumably creating an electron pair, though an occasional photon pair, or even heavier-particle pair, need not necessarily be excluded.

The foregoing hypothesis requires that the cosmic rays of measurable energy reveal a spectral distribution of five distinct, definitely measurable bands, as follows: (1) a band of rays each having an energy of 1.9 billion electron-volts (be-v), produced by the annihilation, or complete transformation, in interstellar space of the rest-mass energy of the helium atom; (2) a carbon-atom-annihilation band, of energy 5.6 be-v; (3) a nitrogen-atom band, of energy 6.6 be-v; (4) an oxygen-atom band, of energy 7.5 be-v; and (5) a silicon-atom band, of energy 13.2 be-v.

The hypothesis requires, further, that there should be in India, for vertically incoming rays, between the magnetic equator and magnetic latitude about  $20^{\circ}$  north, a plateau of cosmic-ray intensity not changing with latitude. This plateau the experiments in India in 1939-1940 brought to light; also, the appearance between Agra (magnetic latitude  $17^{\circ}3'$  north) and Peshawar (magnetic latitude  $25^{\circ}$  north) of a new cosmic-ray band which was identified with the silicon band of energy 13.2 be-v. These results were reported in Year Book No. 40, and more fully in the *Physical Review*, vol. 61, pp. 397-407 (1942).

In spite of absorption in war work, it was possible in December 1941 and March 1942 to make tests in Mexico and in the

United States, which were described briefly in Year Book No. 41 and reported in full in the *Physical Review*, vol. 63, pp. 234-245 (1943). The experimental findings were in accord with the predictions that, since the hypothetical silicon-annihilation rays should have enough energy (13.2 be-v) to get vertically through the Earth's magnetic field at the equator in Peru, though not in India, there should be found, both at sea-level and at all altitudes in the Americas, when vertically incoming rays alone are under test, a very long plateau of uniform cosmic-ray intensities extending north from Mollendo, Peru to about the latitude of Victoria, Mexico (magnetic latitude  $32^{\circ}8'$  north); that there the strong band due to oxygen-annihilation rays (7.5 be-v) should first appear, to be followed, when the magnetic latitude of  $40^{\circ}$  north had been reached, by the full entrance of the nitrogen-annihilation band (6.6 be-v); that in going from Pasadena (magnetic latitude  $40^{\circ}7'$  north) to St. George, Utah, but  $4^{\circ}1'$  (280 miles) nearer to the north magnetic pole, the carbon-annihilation band (5.6 be-v) should appear, to be followed by a plateau clear up to magnetic latitude  $54^{\circ}$  north, when helium-annihilation rays (1.88 be-v) should appear.

The plateau between St. George and Pocatello (magnetic latitude  $51^{\circ}$  north), corresponding to the absence of abundant atoms of atomic weight between that of carbon and that of helium, and the definite appearance of a new band between Omaha (magnetic latitude  $51^{\circ}3'$  north) and Bismarck (magnetic latitude  $56^{\circ}$  north), brought to light in electroscope flights at Omaha and Bismarck, constitute new and strong evidence that the incoming charged particles are electrons, rather than protons or other heavy particles; for in the case of helium there is not enough mass available to permit any heavier particle (proton or mesotron) to acquire the energy of 1.88

be-v that is needed to get to Earth at about latitude  $54^\circ$ .

*Improvement in the resolution of the cloud-chamber method of measuring the masses of mesotrons and the energy-transformations resulting in both their birth and disappearance, by C. D. Anderson, Seth Neddermeyer, and Leon Katz.* About 2000 test stereoscopic photographs have been made with the 24-inch cloud-chamber for the purpose of (1) determining the special properties of the expansion-chamber itself, (2) developing a light-source, (3) providing a suitable Geiger-counter control-circuit, (4) studying the effects of changes in temperature on the distortion of the tracks, and (5) studying various other details.

The chamber produces clear and sharp tracks throughout its whole area. A light-source has been developed which consists of two argon-filled quartz tubes, through each of which a condenser of 48 microfarads capacity and charged to 5000 volts is discharged. This source operates with complete reliability for several thousand flashes and provides sufficient illumination to register tracks with a lens opening of  $F/8$ , which is required to bring the whole depth of the chamber into focus.

As with previous cloud-chamber work, the limit of resolution of the measurements is determined by the distortions of the tracks caused by motions of the gas in the chamber. These motions have been reduced by various means, but further work on this point is required in order to obtain the maximum precision in the measurements made with this equipment. When work is again taken up, it is planned, as a first step, to provide a careful control of temperature of the whole chamber.

Preliminary measurements of curvature of 135 tracks in a magnetic field of 4500 gauss have given the results shown in the accompanying table. More measurements are needed to determine with certainty

whether or not the maxima and minima in the energy-distribution curve represented by these data are real. On the basis of the present data it seems unlikely that they are due simply to statistical fluctuations.

ENERGY INTERVAL IN UNITS OF $10^6$ ELECTRON-VOLTS	NO. OF TRACKS		
	Negative	Positive	Total
0.00-0.45.....	11	17	28
0.46-0.95.....	18	17	35
0.96-1.45.....	7	6	13
1.46-1.95.....	6	11	17
1.96-2.45.....	6	2	8
2.46-2.95.....	8	4	12
2.96-3.45.....	3	0	3
3.46-3.95.....	1	1	2
3.96-4.95.....	0	1	1
4.96-6.95.....	0.5	0.75	1.25
6.96-9.45.....	0.3	0.3	0.6
Above 9.45.....	3	6	9

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#### MASS OF THE MESOTRON

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An expedition to Mount Evans (see Year Book No. 41, p. 102) was made for

the primary purpose of obtaining observations on the mass of the mesotron. The ionization and momentum of cosmic rays were observed simultaneously in a Wilson cloud-chamber by photographing tracks curved by a magnetic field of 2500 oersted, and diffused sufficiently to permit photographic resolution of single droplets. A delay of  $\sim 0.15$  second between reduction of the clearing field from  $\sim 20$  v/cm to  $\sim 2$  v/cm and expansion of the chamber was provided. Most of the photographs were of random expansions, and this time of reduced clearing field corresponds to the interval before expansion during which a track remains to be observed.

Determination of mass from ionization and curvature depends upon a knowledge of the relation between ionization and speed.

Approximately 7000 photographs were taken on Mount Evans, at an elevation of 14,100 feet, and 1800 were taken at Summit Lake, at an elevation of 12,700 feet. The photographs show numerous heavily ionizing tracks with negligible curvature produced by particles—presumably protons—much heavier than mesotrons. These heavy tracks were present in about 8 per cent of the pictures at 14,100 feet and in about 4 per cent of those at 12,700 feet. Each picture records events in an interval  $\sim 0.3$  sec, and in a volume  $\sim 1500$  cc. Only six heavily ionizing mesotrons have yet been identified. Since they are quite conspicuous, it is probable that not many more will be found by additional study of the pictures. Most of the heavy tracks thus do not represent slow mesotrons; in fact, the fraction of slow mesotrons may not greatly exceed the figure 0.001 found by E. J. Williams at sea-level.

Four of these slow mesotrons yield mass values determined as 145 to 210 (probable errors  $\pm 15$  to  $\pm 30$ ) using the formula of Corson and Brode (*Physical Review*, vol.

53, p. 773, 1938), and as 155 to 230 (probable errors  $\pm 15$  to  $\pm 30$ ) using the formula of Williams (*Proceedings of the Royal Society*, vol. A 172, p. 194, 1939). The probable errors are estimated to include chamber distortion of curvature, and statistical uncertainty deriving from the finite number of droplets counted. Curvature was measured by plotting micrometer readings of coordinates along the track and fitting a curve to the points by the method of least squares. The curvature of one track, for example, was determined from 13 points, with a probable error in fitting of 3.5 per cent; the ionization of this track was determined by a count of 335 droplets, hence the statistical error is  $\sim 5$  per cent (or more, since each ion is not the result of a single independent event).

We are grateful to all who have assisted with this experiment, and to the Carnegie Institution of Washington, the Fund for Astrophysical Research, and the Rumford Fund of the American Academy of Arts and Sciences for generous financial support.

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## DIVISION OF PLANT BIOLOGY

*Central Laboratory located at Stanford University, California*

H. A. SPOEHR, *Chairman*

In complete accord with the pattern of activities of the Institution during this period of emergency, the dominant question in this Division has been, What contribution can plant biology make to the war effort? The more immediate aspects of the present conflict have been characterized by extraordinarily complex technical developments. The branches of science basic to these developments have found ready application for their knowledge and skills. By contrast, the biological phases of the conflict have been slower in making themselves apparent, and as a consequence the biological sciences, aside from medicine, have as yet made relatively little direct contribution.

In its more immediate application to the material aspects of human life and the struggle for existence, plant biology contributes essentially to the problem of nutrition. Beyond that, it contributes to the whole matter of the production of carbonaceous material, which, either in the form of highly complex carbon compounds, or as raw material for further elaboration, constitutes the basis of a large part of modern industry. In the great urge for attaining immediate results of industrial value, the fact has been too readily overlooked that, whether for the feeding of a nation or for the synthesis of rubber and plastics, the ultimate source of all the materials is the plant. Sooner or later, our economic planning will be obliged to take this fact into consideration.

The question of the food supply presents the simpler case. The relations between plant, farm, and food are in a very general way familiar to all. Yet a

vast and growing majority, who have not experienced the want of food, take this commodity for granted, without any regard for the tremendous complexities involved in its production and distribution. The relatively very mild restrictions which it has been necessary to impose upon the population of this country during the present emergency have clearly revealed widespread misconceptions regarding the fundamentals of food production for an industrial population.

The only standard of living which is at all basic is the three to five thousand calories, in the form of a diet adequate to maintain human life. Man, from the very biological nature of his being, can never free himself from dependence on this supply of nourishment, and this rests entirely upon the functioning of the green plant. Man stands high in the pyramid of life. It requires innumerable plants to produce a farm animal, and many farm animals to maintain a human life. And this dependence applies to the entire human species, of whatever race or color. In this pyramid of life it is the proportions of the base which determines the survival of some two thousand million souls, each of whom demands his three thousand calories of food. In all the confusion of ideas which this war has produced, this idea stands constantly more clearly revealed. If it is not realized and acted upon by those responsible for the future, the four freedoms will be but empty shibboleths.

In so vast and complicated a situation as is presented by the general problem of the relation of plants to man's well-being, a small group of scientific workers can at best hope for little more than

progress in some particular aspects of the larger problem. This is not the type of problem that will be "solved" by a stroke of scientific genius or through some fortunate chance discovery. Its ramifications are as broad and involved as life itself. It is rather through the accretion of knowledge in many correlated fields, through applying the findings of one branch of science to those of another, and thus "cross-fertilizing" different approaches to the central problem, that sound advance can be expected.

During the past year several projects have been undertaken in this Division with a view to applying to wider usefulness the results and techniques which have been developed in specialized fields. In the field of photosynthetic investigations, a study has been made of the materials produced by diatoms and other algae. In experimental taxonomy, some purely scientific results obtained in the program of evolutionary studies are being applied to the breeding of new forage grasses of importance for food production.

It is rather difficult to realize that in the production of carbonaceous material on the earth, marine diatoms and other algae play a role which is probably quite as important as that of land plants. Diatoms are the principal photosynthetic organisms over about two-thirds of the earth's surface, and they constitute the primary source of food for life in the sea. The investigations which have been carried out during the past year have demonstrated that diatoms and associated organisms possess a photosynthetic apparatus which, in respect to the nature of the pigments, shows some remarkable differences from that of land plants. It remains to be determined whether these differences in the photosynthetic apparatus are reflected in the nature of the products formed and

in the mechanism of the photosynthetic process.

The investigations on diatoms and other algae have also been directed to the determination of the nature of the organic material which is produced by these organisms. In this connection an extensive series of experiments has been carried out to establish to what extent the composition of these organisms can be influenced by different environmental conditions. For example, can conditions be found under which they produce materially larger quantities of fats or hydrocarbons than normally? As a matter of experience these lower organisms have been found to show a high degree of flexibility in regard to the conditions under which they can live, and similarly to show very considerable variation in their composition under these different conditions. It is now possible, therefore, to select a set of culture conditions (certain mineral nutrients, carbon dioxide concentration, and light intensity, for example) and obtain, with a high degree of reproducibility, a culture of the organism having a certain composition, and under another set of conditions to obtain a culture of quite another composition.

Mention may be made of one direction in which the results obtained from these experiments may be of use. It has been assumed for a long time that some of our petroleum deposits owe their origin to the activity of diatoms during past geological eras. This assumption constitutes an important part of geological theory, and on it considerable reliance is placed for exploration of new oil fields. Yet virtually nothing is known concerning the materials produced by the living diatoms. These geological theories are largely a matter of inference, yet they constitute important tools for decidedly practical ends. One essential feature of

these theories, namely the functioning of the diatoms, remains beyond the practical test of the geologist. That test is primarily a biochemical task. An experimental contribution to our knowledge of the mode of functioning of diatoms and the nature of the substances produced by them, with some regard to the geological implications, may give added support to the current geological theories or indicate how they should be modified.

During the past year the program in experimental taxonomy has advanced to an analysis of relationship between natural plant units of higher order, up through the genus. It is now clear that in the plant kingdom the tempo of evolution may vary greatly, depending on the stage of development that a group has attained. At one extreme there is the very slow accumulation of hereditary differences through mutation, gene exchange through hybridization, and natural selection, which ultimately may result in the development of new species. At the other extreme, new species may arise suddenly through the addition of all the chromosomes of distinct species following hybridization, a process called amphiploidy. Before new species can arise by this method, however, their parents must pass through an age-long process of differentiation, during which their entire sets of chromosomes, instead of the genes, become the evolutionary building units.

An inquiry into the requirements for successful amphiploidy was prompted by the origination of three new *Madiinae* in this laboratory by this method. The resulting survey, including other cases on record, clarified the relations between remotely connected species complexes, and thereby rounded out the study on the principles that govern the various degrees of relationship that can be experimentally determined.

Amphiploidy has been a highly important mechanism in plant evolution, enabling many groups to pyramid their chromosome sets in progressively higher series, thereby combining the inheritances of their members. Also, amphiploids combine the new vigor of hybridity with the stability of independent species. Consequently, they are frequently superior in performance to their parents and more adaptable, especially when they have brought together the inheritances of species suited to ecologically different environments.

Many of our most important crop plants appear to have evolved by this process, and they belong to genera that have reached the stage of evolutionary maturity where amphiploidy is successful. Plant breeding by the addition of unbroken sets of chromosomes of remotely related species from such genera offers promise of better plants for the horticulturist, the agronomist, and the soil conservationist. This method also makes it possible to combine the inheritances of forms from extreme climates and habitats to produce new ones well adapted for intermediate environments, thereby utilizing for breeding purposes previously untapped supplies of genes.

A program of breeding range grasses has been initiated this year, in which these principles are applied. The experiments are being conducted in cooperation with the Soil Conservation Service of the U. S. Department of Agriculture, which is supplying much of the breeding stock. The grasses used are mostly native races from the Pacific Northwest that have been tested in regional nurseries and found to be superior. In addition, strains from the Institution's transplant station transect are being used. The plan is for the Institution staff to make the crossings and to test the constancy of the products. These are then

to be turned over to the Soil Conservation Service for propagation, testing, and dissemination. In the few crossings that have been attempted this year, races of bluegrass, the genus *Poa*, were employed. These crossings are to be extended next year, and the wheat grasses (*Agropyron*) are to be included, for members of this genus, like *Poa*, are economically of great importance and supposedly suitable for improvement through controlled amphiploidy.

The work of completing the program on desert investigations has been considerably hampered by the difficulty of automobile travel for field investigation. A large amount of material has been prepared for publication covering the extensive studies of the distributional, taxonomic, and geographical features of the Sonoran and Chihuahuan deserts. The vegetation of deserts and semideserts is particularly noted for the variety of plant types it displays. One of the most important and yet most difficult problems of the desert is the attempt to find the geographic source of its various plant types and to learn something of the stages by which their special modifications have come about. Therefore, considerable time has been given to assembling the facts which bear on this problem. The questions of origin, movement, and modification are being considered in close connection with what is known of the desert environment and of the ecological behavior of desert plants.

The field studies in paleobotany have also suffered because of the inability to travel by automobile and because much of Dr. Chaney's time has been taken up with work connected with the war. The discovery of the remains of a plant closely resembling the prickly pear, *Opuntia*, in sediments which date back to the Middle Eocene is very remarkable. Usually only

plants with definitely woody stems, or with hard leaves and fruits, are likely to be preserved in the rocks. These structures must be buried in sediments or they will soon be destroyed by decay. Trees which live near lakes or streams more readily become a part of the fossil record than those which live on the uplands or in deserts. Even if they have resistant structures, plants growing far from sites of sedimentary deposition seldom leave the imprint of their existence in the rocks. It is not surprising that members of the cactus family are rarely reported as fossils. Their fleshy stems are poorly suited to preservation, and they commonly live in exposed or hilly situations where erosion rather than deposition is going on.

The Cactaceae have highly specialized vegetative structures, and might be expected to have evolved in comparatively late geologic time, coincidentally with the development of widespread aridity in the Pliocene epoch. If, as botanists have supposed, the fleshy, almost leafless stems of the cactus are a response to aridity, it seems clear that there have been deserts and desert specialization far back into the early days of angiosperm development. Of the fossil material collected by Mr. Earl Douglass in the twenties, and recently studied by Dr. Chaney, one specimen shows five attached joints, two of which are interpreted as representing reproductive structures. No evidence of spines has been noted, though areoles like those to which spines are attached in living cacti may be noted on the fossil stems. Several minor differences between these ancient plants and the modern prickly pear seem to justify their reference to a new genus, *Eopuntia*—the dawn cactus.

Such rare discoveries, representing the plants which lived beyond the limits of the humid forests, suggest the nature of

past vegetation in environments which are almost completely unknown. This ancient cactus material also projects back to an early epoch the date of high specialization in flowering plants. With its im-

plication of climatic and topographic diversity in the Eocene, it provides additional background for our understanding of the evolution of varied races of mammals in the early days of our era.

## BIOCHEMICAL INVESTIGATIONS

H. A. SPOEHR, J. H. C. SMITH, H. H. STRAIN, W. M. MANNING, H. W. MILNER, AND G. J. HARDIN

### BIOCHEMISTRY OF ALGAE

It has long been recognized that diatoms and other algae play a very important role in the carbon economy of the earth. Over the major part of the earth's surface these plants are the principal photosynthetic organisms. They constitute the primary food for life in the sea and in the lakes, and are presumed to have had an important part in the formation of petroleum. Yet very little is known regarding the biochemistry of these organisms, of what materials they are composed, what substances are formed in the course of their photosynthetic activity, and in what respects they differ chemically from land plants. The latter, probably because they constitute man's first and chief source of materials for food and the arts, have been subjected to extensive investigation. Land plants also exhibit tremendous diversity in form and structure, and in a measure this diversity is reflected in a great variety of chemical compounds which are formed in the bodies of the plants and for which they have become significant to man. In at least one respect, however, land plants, of even the most diverse character, show a remarkable uniformity, namely in the composition of their photosynthetic apparatus, more particularly their chloroplast pigments. On the other hand, marine plants, which show much less diversification in their vegetative features than do land plants, have now been found to have photosynthetic pigments which differ from those of land plants and which vary be-

tween one species of marine organism and another.

The significance of these differences in photosynthetic apparatus between land and aquatic plants is as yet not clear. There may be clues here to aid in unraveling the evolutionary development of plants from past geological eras and in establishing the phylogenetic relationships of the marine organisms themselves. It may be that associated with these differences in the photosynthetic apparatus will be found variations in the photosynthetic process itself and in the substances which are produced. The elucidation of these problems is primarily dependent upon careful experimentation.

For experimental purposes algae offer some striking advantages over land plants. Although the isolation of most algae in pure culture is often associated with many difficulties and the discovery of the most favorable conditions for growth entails an enormous amount of patient research, when these obstacles have been overcome there can be made available an almost limitless supply of material which is very favorable for biochemical and physiological investigation. Most algae under favorable conditions show a rapid growth, so that a "crop" can be obtained in short time. Some of these organisms can also be subjected to a wide range of experimental conditions, such as temperature, light intensity, and salinity of the culture solutions, without injury. Since the organisms are contained in liquid media, controlled

conditions can be maintained more easily than with land plants.

#### SELECTION AND ISOLATION OF ALGAE

The task of selecting and isolating organisms which are favorable for biochemical and physiological experimentation has been assigned to Dr. Hardin. Some twenty species have been investigated.

It is necessary, or at least highly desirable, to have pure cultures of algae, that is, single-species cultures free of all other organisms including bacteria. Such cultures are, of course, more difficult to obtain than are cultures which are species-pure only, since one always starts with a culture in which the algae are outnumbered by bacteria, however conspicuous the algae may be. Growing the culture in an inorganic medium reduces the disparity of numbers, but does not eliminate it, for the medium is never strictly inorganic. Even if contaminating organic substances are not introduced with the salts and with the distilled water used in making the medium, some organic matter will later appear as a result of the growth of the algae. Whether this organic matter represents a portion of the photosynthate directly liberated into the medium, or whether, as is more likely, it has its source in the autolysis of some of the cells, does not matter in this connection. In either case, by the time an algal population has grown to a considerable size the dissolved organic matter present is enough to support an even larger population of bacteria.

With such a mixed culture, Lister's dilution method (with which the first pure cultures of bacteria were obtained) is impracticable. Theoretically it could work no matter how low the proportion of desired organisms, but only at the expense of an excessive amount of time and materials.

The agar streak method is likewise, in general, not very satisfactory for the isolation of algae. Although it has been possible thus to isolate a species of *Chlamydomonas*, the method generally fails on account of the overgrowth of the algal colonies by the spreading bacterial colonies. The method can be improved in several ways: (1) The growth of the colonies can be followed microscopically, and a micro-colony of algae can be transferred to other media before bacteria have overgrown it. By this means, a pure culture of another unidentified species of *Chlamydomonas* has been obtained. (2) The bacterial predominance in the original liquid culture can be reduced by several gentle centrifugations of the algae. A pure culture of *Selenastrum gracile* has been obtained in this way. (3) Substances may be introduced into the medium which are more toxic for bacteria than for algae. Potentially this is a most useful method, but practically it involves the problem of empirically testing a world of substances, with no assurance of success, especially since in general bacteria are believed to be more resistant to poisons than are algae. It has been found, however, that a few fresh-water algae are more resistant to sudden change to a sea-water medium than are most bacteria, so that by using agar plates made with sea water it has been possible to free two fresh-water algae, *Stichococcus bacillaris* and *Microthamnion Kuetzingianum*, of bacteria.

The spreading of bacteria which is so objectionable with surface colonies can be largely prevented by using the pour-plate method. A small sample of the crude culture is mixed with liquid agar which has been cooled nearly to the gel point, and the mixture immediately poured into a Petri dish to cool and solidify. By this means one obtains deep rather than surface colonies, and such deep colonies of

bacteria generally remain spherical or lenticular masses of not more than a few millimeters diameter with little tendency to spread; consequently any algal colonies present have a reasonable chance of remaining pure. A number of the Chlorophyceae have been purified by this method, but it has proved less useful for diatoms, because of the diatoms' greater sensitivity to heat. The agar, in order to remain liquid, must be at a temperature of more than 40° C. at the time of introduction of the algal sample. Even brief exposure to such temperatures is fatal to many diatoms, though not so to *Nitzschia Palea*, *N. fonticola*, and *N. Kuetzingiana*, which three species have been purified by this means. In the case of *N. Palea* the actual process of purification was aided by the activities of the diatom cells themselves, which, starting from a deep colony contaminated with bacteria, migrated outward through the agar leaving the bacteria behind. This ability of some pennate diatoms to scrape themselves free of bacteria by migrating through 1.5 per cent agar has been previously noted by Meinhold (1911). The spreading of surface colonies of diatoms does not accomplish the same end; at least, no success has followed attempts thus to purify *Nitzschia Palea* and *Hantzschia amphioxys* var. *pusilla*.

If a microbe can be easily seen with the relatively low power of a dissecting microscope, and especially if it is motile, it may often be purified by a washing process, that is, by transferring one or several cells from one dish of sterile fluid to another, until all the bacteria have been left behind. This method has yielded pure cultures of *Chlamydomonas* sp., as well as of the colonial green algae *Pandorina morum* and *Gonium pectorale*. It is somewhat surprising that an alga such as *Pandorina*, surrounded by a copious jelly,

can be freed of bacteria merely by washing. One might expect that the jelly, being extracellular, would be infested by bacteria, as are the gelatinous sheaths of many blue-green algae. *Pandorina* must have some means of preventing the adherence or growth of bacteria.

With diatoms, the washing technique has yielded few good results. Pennate diatoms tend to stick to the substrate. This causes difficulty in removing them from the bottom of a dish with a micropipette, and still more in blowing them out of the pipette into the next dish. Most of the small forms attach themselves so firmly to the walls of the micropipette that it is impossible to dislodge them alive. Only with one large form, *Hantzschia amphioxys* var. *elongata*, has this method succeeded. Apparently the adhesive power of this form is small relative to its bulk.

With centric diatoms the washing method has been completely unsuccessful. The marine planktonic forms which were used showed no tendency to stick to the substrate, but the cells or filaments either could not be freed of bacteria, or, when so freed, would not grow in the media used. Centric diatoms, as a group, seem to be more difficult to grow in any sort of laboratory culture than are the pennate forms. So far, it has been possible to grow only two species in large enough quantities for other studies, these species being *Thalassiosira gravida* and *Stephanopyxis turris*. An impure culture of the latter has been found to grow quite well, with a maximum fission rate of 0.5 fission per day, in sea water enriched with nitrate, phosphate, and silicate, provided a small amount of "soil extract" is also present. The character of the sea water itself is evidently important, for samples collected at different times are not equally suitable, some being quite toxic. Whether the toxicity is due to some sort of littoral contamina-



tion, or to other factors, will not be investigated, for it has been found possible to replace the natural sea water by an artificial medium based on Dittmar's old analysis of sea water.

Algae of some other classes are even more intractable than centric diatoms. The greater part of the physiological studies made to date have been carried out with easily culturable members of the class Chlorophyceae, and of these most have been members of the single order Chlorococcales, to which *Chlorella* and *Scenedesmus* belong. Consequently it is suspected a priori that generalizations about the physiology of algae rest on none too secure a foundation. Furthermore, if differences in storage products indicate differences in some of the preceding metabolic steps (a not unreasonable assumption), an additional reason is seen for desiring information about other classes. The Chlorophyceae, with few exceptions, store sugar or starch. The great groups of oil storers, the Bacillariae (diatoms), Xanthophyceae (yellow-green algae), Chrysophyceae (golden-brown algae), and Dinophyceae (dinoflagellates, etc.), besides the less abundant Cryptophyceae and Chloromonophyceae, have all suffered great neglect by physiologists, the reason being that nearly all of them are difficult to culture. Notoriously difficult to grow in the laboratory are the Chrysophyceae, though some of the members of this class (e.g., *Synura*) at times give rise to spectacular natural "blooms." Since these organisms are generally rare or missing in most bodies of water, it may be suspected that they have very particular requirements, now quite unknown.

Given the proper conditions, "rare" algae often become exceedingly numerous. An opportunity to study one of the less common algae was presented when a bloom of the dinoflagellate *Peridinium cinctum*

was found in an outdoor concrete tank. It was estimated that well over 95 per cent of all the algal cells present were of this single species, and the natural culture held its own for the two months that the tank was available. Attempts to grow the dinoflagellates in the laboratory under a great variety of conditions met with uniform failure.

Algology is in great need of a technique equivalent to the "selective culture" method of bacteriology (also called "enrichment culture" or "elective culture"), by means of which one can obtain whatever sort of bacteria is desired. If one wishes to study an organism capable of utilizing inulin, one makes a medium containing inulin as the only energy source and inoculates it with soil or some other unknown mixture of microbes, and presently the inulin-decomposing organisms, having a competitive advantage, outmultiply all other organisms. To get a pure culture of these organisms one uses, of course, the same inulin-containing medium used for the selective culture.

With the autotrophic organisms, however, the problem is more difficult; for example, what chemical should one use to select an oval, uniflagellate cell, having a red eye spot, two contractile vacuoles, and golden-brown lateral platelike chromatophores? Where is the logic to connect the morphological characteristics of the organism with its physiological requirements? Attempts have nevertheless been made to discover selective cultures for algae. The concentrations of various inorganic salts have been varied in a number of ways, according to more or less intuitive and uncertain hypotheses. In this way a number of selective cultures for different Chlorophyceae have been found. Selective media have also been found for the yellow-green alga *Tribonema bombycinum* and a fresh-water centric diatom of the genus

*Melosira*. Whether other useful selective media can be found by this blindly empirical method, or whether the search will, in terms of time and effort, prove too expensive to warrant continuing, remains to be seen.

chlorophyll *a* and  $\beta$ -carotene, have been found in all plants examined.

The occurrence of pigments in plants belonging to different major groups is shown in the accompanying table. Because of the difficulty in obtaining adequate

THE OCCURRENCE OF PIGMENTS IN VARIOUS GROUPS OF PLANTS

(+ indicates the presence of the pigment, — its absence; ? small quantities that may have come from contamination of the source by other organisms; a blank space signifies that a thorough search was not made for the pigment. Carotenes other than  $\beta$ -carotene and several minor pigments of higher plants have been omitted.)

Pigment	Higher plants	Green algae	Euglenophyceae	Brown algae	Diatoms	Dinoflagellates	Yellow-green algae	Red algae	Blue-green algae
$\beta$ -carotene	+	+	+	+	+	+	+	+	+
Chlorophyll <i>a</i>	+	+	+	+	+	+	+	+	+
Chlorophyll <i>b</i>	+	+	+	—	—	—	—	—	?
Chlorophyll <i>c</i>	—	—	—	+	+	+	—	—	—
Chlorophyll <i>d</i>	—	—	—	—	—	—	—	+	—
New chlorophyll	—	—	—	—	—	—	?	—	—
Lutein	+	+	—	—	—	—	—	—	—
Zeaxanthin	+	+	—	—	—	—	—	—	—
Violaxanthin	+	+	—	+	—	—	—	—	—
Neoxanthin	+	+	—	—	—	—	—	—	—
Flavoxanthin	+	+	—	+	—	—	—	—	—
Fucoxanthin	—	—	—	+	+	—	—	?	—
Neofucoxanthins	—	—	—	+	+	—	—	?	—
Peridinin	—	—	—	—	—	+	—	—	—
Dinoxanthin	—	—	—	—	—	+	—	—	—
Diadinoxanthin	—	—	—	?	+	+	—	—	—
Diatoxanthin	—	—	—	?	+	—	—	—	—
Myxoxanthin	—	—	—	—	—	—	—	—	+
Myxoxanthophyll	—	—	—	—	—	—	—	—	+
Unnamed xanthophylls	—	—	—	+	—	—	+	—	—

#### PIGMENTS OF ALGAE

Closer examination of the pigments from plants in various botanical families reveals some remarkable variations in the nature of the chloroplast pigments. These variations are especially striking among the pigments of algae, which have been investigated by Drs. Strain and Manning. The total number of chloroplast pigments found in various plants now exceeds two dozen. Only two of these,

quantities of many species, our information is far from complete. There are indications that additional work will reveal new chlorophylls and many new xanthophylls in the photosynthetic tissues of different autotrophic plants.

*Higher plants and green algae.* The nature of the pigments occurring in higher plants has been established by previous investigations. Some attention has been given to the pigments of three or four

species of green algae, especially *Chlorella pyrenoidosa*. On the basis of these limited data, the major constituents of green algae appear to be identical with those of higher plants. These pigments are chlorophylls *a* and *b*,  $\beta$ -carotene (plus considerable amounts of  $\alpha$ -carotene in *Chlorella* and *Stigeoclonium*), lutein, zeaxanthin, and probably violaxanthin, neoxanthin, and flavoxanthin.

A preliminary examination of *Euglena gracilis*, a green-colored flagellated alga, showed the presence of chlorophylls *a* and *b*, but some of the xanthophylls differed from those of true green algae and higher plants.

*Brown-colored algae (diatoms, brown algae, dinoflagellates, and allied forms).* It was emphasized in last year's report that none of the xanthophylls found in the diatom *Nitzschia closterium* were identical with those of higher plants. Five additional species of diatoms, including centric as well as pennate forms, have been examined, with the same result. One of these diatoms, *Navicula torquatum*, was found to contain considerable quantities of a hitherto undescribed pigment having the general properties of a carotene, but with an absorption spectrum closely resembling that of violaxanthin. None of the other algae examined contained detectable quantities of this carotene-like pigment, which we propose to call  $\epsilon$ -carotene.

A dinoflagellate, *Peridinium cinctum*, has been found to contain larger quantities of chlorophyll *c* than any of the diatoms and brown algae thus far examined. Peridinin, the principal xanthophyll of *Peridinium*, resembles fucoxanthin, but is redder. Fucoxanthin was not found in *Peridinium*. Two other xanthophylls were obtained in appreciable quantities; one was identical with a xanthophyll of diatoms (diadinoxanthin), whereas the

other has not been reported previously. *Peridinium* also apparently contains none of the xanthophylls found in higher plants.

A small unicellular, brown-colored alga was found growing in the tissues of a common Pacific coast sea anemone, *Bunodactis xanthogrammica*. The pigments of this alga were found to be identical with those of the dinoflagellate *Peridinium*. Although the alga from *Bunodactis* lacks some of the morphological characteristics of dinoflagellates, the identity of pigment make-up suggests that it is probably a member of some closely related algal group.

Brown algae, like diatoms, contain chlorophyll *c* (chlorofucine) as the second green pigment, and fucoxanthin as the principal xanthophyll. Whether or not they contain traces of the other xanthophylls found in diatoms cannot be decided until pure (or unialgal) cultures of brown algae are available. In addition, brown algae contain small quantities of two or three of the xanthophylls found in leaves, along with a new xanthophyll resembling neoxanthin and a similar pigment found in flowers of the pansy.

*Red algae.* As reported last year, various red algae have been found to contain a new chlorophyll (chlorophyll *d*) which absorbs light at considerably longer wavelengths than does chlorophyll *a*. Some of the properties of chlorophyll *d* are described below, in the section on chemical properties of the chlorophylls. Neither chlorophyll *b* nor chlorophyll *c* has been found in red algae.

The carotenoids of red algae have not been examined, but it has been noted that several are present in considerable quantities. The occurrence of a unique chlorophyll suggests that a search might also reveal new xanthophylls.

*Blue-green algae.* A preliminary examination has been made of the pigments

of a species of *Phormidium*. Chlorophyll *a* was found, but not chlorophyll *c* or chlorophyll *d*. The presence of chlorophyll *b* was doubtful.

The two principal xanthophylls of *Phormidium* appeared to be identical with those previously found in blue-green algae by other investigators. These two xanthophylls were not observed in the other groups of algae. Several other xanthophylls were present in *Phormidium*, but have not been investigated further.

*Yellow-green algae.* In recent years, because of certain morphological and physiological similarities, many algologists have considered yellow-green algae and diatoms to be related. However, the pigments of the one yellow-green alga we have examined, *Tribonema bombycinum*, show little resemblance to those of diatoms, or to those of any other group of algae. Chlorophylls *b*, *c*, and *d* were not detected. In addition to chlorophyll *a*, very small amounts of another green pigment were present in the extracts of *Tribonema*, but it is not yet certain that this pigment represents a natural constituent of the alga. At least three xanthophylls were present, but none of the three examined appeared identical with any previously reported xanthophyll.

*Significance of pigment diversity.* The great diversity of pigments in the various groups of algae is interesting from several points of view. The results present a challenge to the organic chemist. Much has been learned about the structure of chlorophylls *a* and *b* as a result of years of intensive research. Similar information concerning chlorophylls *c* and *d* may provide a better basis for generalizations regarding the type of molecular structure necessary in the photosynthetic process. A similar advance in our knowledge of the many different carotenoids found in algae

will establish the degree of natural structural variation in this class of pigments.

The diversity of pigments is also interesting because it suggests the possibility of variation in the mechanism of photosynthesis in different groups of plants. This variation in the mechanism would be likely to lead to different products.

Finally, the results shown in the table may provide an indication of the degree of phylogenetic relationship between the various classes and divisions of plants. Support for this view is derived from the following considerations: (1) Pigments related to the photosynthetic apparatus reflect some of the basic characteristics of the genetic make-up of a plant; (2) certain plastid pigments appear to be restricted to given groups of plants, although the relative amounts may vary in different members within a class.

It may be seen that chlorophyll *a* and  $\beta$ -carotene are common to all the plant classes which have been examined. This is consistent with the hypothesis of a common origin for all plants.

Chlorophyll *b* occurs only in higher plants, green algae, and the Euglenophyceae. Some of the xanthophylls of *Euglena* are not identical with those of green algae and higher plants. These statements are consistent with the accepted view that higher plants have evolved indirectly from green algae, and also suggest that *Euglena* is remotely related to the green algae.

Brown algae, diatoms, and dinoflagellates may be regarded as more closely related to one another than to other groups, because (1) all contain chlorophyll *c* as the second green pigment, (2) diatoms and brown algae contain fucoxanthin in common, (3) diatoms and dinoflagellates both contain diadinoxanthin. Since the brown algae also contain one or more xanthophylls found in green plants, it is possible

that they constitute a connecting link between the green and brown plants.

The pigment composition of *Tribonema* suggests that the yellow-green algae (Xanthophyceae) are not closely related to diatoms, or to any of the other classes examined. This is perhaps the only instance where the pigment evidence is in actual disagreement with conclusions reached from other lines of evidence.

The fact that red algae appear to be the only class containing chlorophyll *d* is a further indication that this class of algae is remote from the other classes. A more complete study of the pigments of red algae, and also of blue-green algae, is certainly to be desired.

#### EFFECT OF ENVIRONMENT ON PIGMENT CONTENT OF ALGAE

Other investigators have reported that various environmental factors may influence the pigment concentration, especially the chlorophyll concentration, of various plants. In the last annual report, there was described a marked effect of light on the concentration of a diatom xanthophyll (diadinoxanthin, in *Nitzschia closterium*).

Further evidence of the influence of light, as well as of other factors, on pigment concentration has been obtained from a study of cultures of the green alga *Chlorella pyrenoidosa*, grown by Dr. Spoehr and Mr. Milner. Both the chlorophyll and carotene concentrations (per unit dry weight) varied by a factor of approximately 25, the highest concentrations occurring in young cultures grown at low light intensity, and the lowest concentrations being observed in older cultures grown at high light intensity. The total amount of carotenoid pigments relative to chlorophyll was higher in the cultures containing little chlorophyll than in those containing much chlorophyll. Decrease in the amount of yellow and green pigments in

older cultures, especially in those exposed to strong light, does not result from a simultaneous increase in the total amount of organic matter present, but from an absolute decrease in the total amount of pigment present.

In *Chlorella* cells grown at low light intensity the amount of  $\alpha$ -carotene usually exceeded the amount of  $\beta$ -carotene, but in cells grown at high light intensity the reverse was true. This effect has not been observed before, nor have other plants been found in which the amount of  $\alpha$ -carotene exceeds that of  $\beta$ -carotene.

The surprisingly large capacity for variation in pigment content shown by *Chlorella* has obvious practical implications. It indicates that more general use might be made of controlled environments for efficient production of other specific substances. Capacity for variation with change in environment may not be confined to pigments.

#### PROPERTIES OF CHLOROPHYLLS

Chlorophylls *a*, *b*, and *d* have been found to undergo spontaneous, reversible isomerization reactions. The reactions take place slowly in solutions at room temperature, rapidly at higher temperatures. Chlorophyll *a* yields a single product, chlorophyll *a'*, which is less adsorbed than chlorophyll *a* upon columns of sugar. These two pigments show similar absorption spectra and yield similar but distinct pheophytins. Chlorophyll *b'*, the isomerization product of chlorophyll *b*, differs but slightly in absorption spectrum and adsorbability from the original chlorophyll. At equilibrium, the new isomers constitute about a fifth of the pigment mixtures.

Chlorophyll *d* yields a more complex isomerization mixture. One isomer, chlorophyll *d'*, differs only slightly from chlorophyll *d* in spectral properties. Another isomer, isochlorophyll *d*, is formed in con-

siderable quantities and is similar to chlorophyll *a* in its spectral absorption properties. A third isomer, isochlorophyll *d'*, differs but slightly from isochlorophyll *d*.

These isomerization reactions complicate investigations of the properties of the chlorophylls. Thus far they have not been observed to take place in living plants, but they occur rapidly when fresh plant material is heated.

As is the case with the common chlorophylls *a* and *b*, chlorophyll *d* and its isomers contain magnesium. When the magnesium is removed from chlorophyll *d* with acid at low temperature ( $-80^{\circ}\text{C.}$ ), an unstable pheophytin, pheophytin *d*, is formed. With acid at room temperature, another more stable pheophytin is obtained. The latter, isopheophytin *d*, is also obtained from isochlorophyll *d* with acid at low temperature. The less stable pheophytin apparently has the same molecular arrangement as chlorophyll *d*. The more stable pheophytin has the same arrangement as isochlorophyll *d*. The two pheophytins are also interconvertible. Introduction of magnesium into the isopheophytin *d* molecule results in the regeneration of isochlorophyll *d*. In spite of the spectral similarity of isochlorophyll *d* and chlorophyll *a*, these two pigments yield spectrally different products when treated with alkali and acid.

These isomerization reactions give further indication of possible variation in the photosynthetic apparatus of plants. They must also be considered in the isolation of chlorophyll pigments and in studies of the reactions of these substances.

#### THE PRODUCTION OF ORGANIC MATTER BY *CHLORELLA PYRENOIDOSA*

The investigations on the characterization of pigments can be carried out with relatively small amounts of algal material, thanks to the chromatographic and spectral

absorption methods which have been devised during the past few years. For the investigations on other components of these plants, larger quantities of material were required, especially because it was desired to determine the influence of certain environmental factors on the production of particular components. These investigations were carried out by H. A. Spoehr, H. W. Milner, and Garrett Hardin. The culturing of any microorganism in quantity presents some problems which are peculiar to each organism and some which are common to the general method which is adopted. Although a number of microorganisms, including some diatoms, were cultured in larger amounts, special attention was given to *Chlorella pyrenoidosa*, because we had had more experience with this organism than with any of the others and the effects of changes in environmental conditions could be more rapidly worked out with this one organism. Also, the methods of chemical analysis which were to be applied to these algal investigations could be more satisfactorily tested on this material than on any other which had thus far been cultured.

Two-liter and 15-liter cultures of *Chlorella* were grown. The vessels, fitted with tubes for aeration and containing the mineral nutrient solutions, were sterilized before inoculation. The 15-liter cultures were grown outdoors under north skylight; the 2-liter cultures, cooled by running water, were illuminated from below by incandescent lamps. Carbon dioxide, in air or in nitrogen, was the only source of carbon. After the cultures had grown the desired length of time, which varied according to experimental requirements, the organisms were separated from the culture solutions by centrifugation. The yields varied considerably according to the culture conditions used. Excluding the obviously unfavorable conditions, the yields were about

2 grams per liter on a fresh-weight basis. In some cultures the dry weight showed great variation, ranging from 11 to 39 per cent.

*The degree of reduction of carbon.* Consideration was given primarily to the organic constituents produced by the algae. For the purposes of this investigation the determination of the organic composition of the plants by means of chemical estimation of particular compounds, or even of groups of compounds, was too slow and cumbersome because of the large number of experiments involved. Since the entire organic content of the plant was regarded as arising from the reduction of carbon dioxide, the energy level of this total organic content was of more concern than the amounts of any particular constituents. A method was, therefore, devised for determining the "degree of reduction" of the organic material constituting the entire body of the plant culture. This "degree of reduction" has been designated the R-value, and is based on the percentage of carbon, hydrogen, nitrogen, and oxygen of the dry plant material, as determined by combustion analysis. The R-value can be obtained by calculating the amount of oxygen necessary to oxidize completely the carbon and hydrogen content of the plant material. If carbon dioxide is taken as the lowest stage of reduction of carbon, with an R-value of zero, and methane as the highest stage, with an arbitrary value of 100, all organic compounds fall between these extremes and their R-value can be readily calculated. For example, the R-value of malic acid is 17.94, cellulose 29.70, alanine 33.76, leucin 50.45, triolein 72.48, hexane 88.42. A plant takes in carbon in its most oxidized form, carbon dioxide, and from this as the only source of carbon builds all the organic material constituting its body. A determination of the R-value will, therefore, be an over-all measure of

how far it has carried the reduction of carbon dioxide.

The body of a plant is, of course, composed of a great many different carbon compounds. Is it of fixed composition? Do different components of the plant vary in amount, and to what extent can these different components be altered by changes in the environmental conditions to which the plant is exposed? Changes in composition would be reflected in different R-values. Higher R-values indicate relatively greater amounts of highly reduced compounds such as fats and hydrocarbons; lower R-values indicate relatively larger amounts of less reduced compounds such as carbohydrates and hydroxy acids.

A survey of the leaves of a number of higher plants of widely different genera showed that their R-values are within a relatively narrow range, from about 30 to 40. Some of these leaves show very marked quantitative variation in some of their components, before and after a period of illumination. Notable starch synthesizers, such as *Nicotiana tabacum* and *Tropaeolum majus*, the leaves of which increase 10- to 20-fold in starch content after a period of illumination and in which the starch constitutes finally 20 to 44 per cent of the dry matter, showed but a small decrease in R-value after a period of illumination.

The lower plants, for example *Chlorella*, appear in some respects to be more flexible than the higher plants. This alga can grow under a wide variety of environmental conditions, and thereby undergoes considerable change in composition. That this change not only is quantitative but results in products of different chemical composition is indicated by the fact that its R-values range from 38 to 58 according to environmental conditions.

An extensive series of culture experiments was carried out with *Chlorella* in

order to determine the effect of different environmental factors on the production of organic matter by this organism. More particularly, an effort was made to discover the conditions which were favorable to the production of compounds of high R-value, presumably fats and hydrocarbons.

*Environment and chemical composition.*

In an investigation entailing so complex a system as is involved in the culture of *Chlorella*, it is manifestly impossible, without the expenditure of an inordinate amount of time, to give full consideration to each member of the constellation of environmental factors. Consequently, certain of the components of each group of environmental factors, which from past experience appear to be most significant, were selected. Thus, of the mineral nutrients, primarily nitrogen and to some extent phosphate and potassium were given consideration. Of the gases, primarily the effects of carbon dioxide concentration were studied, and to some degree the partial pressure of oxygen. Of the light factor, primarily intensity, the effect of intermittency, and the duration of illumination received attention. Studies of the effect of temperature have only recently been started. Obviously none of these factors can be considered entirely independently of the others. Moreover, the choice of the factors investigated was in part influenced by the theories regarding the nature and intensity of these factors during past geological eras, so far as it has been possible to envisage them. That is, on the assumption that petroleum deposits have arisen from the activity of certain marine organisms, consideration was given to the conditions which are presumed to have prevailed at the time these organisms lived. Thus far, over one hundred and fifty 2-liter cultures, grown under a considerable range of conditions, have been harvested and the product analyzed.

Some of the more promising of these have in turn been grown in larger culture for more particular analysis.

The concentration of carbon dioxide has a considerable effect on the composition of the organic material produced by *Chlorella*. Not only was the yield greater, as was to be expected, with addition of carbon dioxide to air, but such cultures also showed a higher R-value. The highest yields and also the highest R-values were obtained with 5 per cent carbon dioxide with high light intensities. Ten per cent carbon dioxide gave lower yields and lower R-values, even with high light intensities. Under most conditions it appears to make little difference in yield or in R-value whether the carbon dioxide is mixed with air or whether it is contained in nitrogen or hydrogen, that is, whether it is an aerobic or anaerobic culture. With higher light intensities and longer periods of illumination, however, 5 per cent of carbon dioxide in nitrogen produced higher yields and higher R-values than 5 per cent carbon dioxide in air. No satisfactory explanation has as yet been found for this complex interaction of several factors, which will require considerably more detailed study. With the more extreme condition of mixtures of carbon dioxide and oxygen, in the absence of any other gas, very pronounced effects are observable: the cultures grow exceedingly slowly and produce small yields with a very low R-value.

Of the three mineral nutrients studied, nitrogen, potassium, and phosphate, the first two appear to exert a pronounced effect. Since the interpretation in terms of plant metabolism of effects obtained by variations of any one required mineral element may be exceedingly complex and such effects may be obscured in various ways, this summary is confined to the observed gross effects on yields and R-values



produced by different concentrations of these mineral elements in the solutions in which the *Chlorella* cells were cultured. Nitrogen, as ammonium ion, has a profound effect on both yield and R-value. The highest R-value, 56.8–58.4, was obtained from cultures from which nitrogen compounds were omitted, although the yields were low. Addition of even very small quantities of nitrogen materially increased the yields and resulted in lower R-values. With 0.12 g.  $\text{NH}_4\text{Cl}$  per liter, maximum yields were obtained, with R-values of about 53. Further increasing the amount of nitrogen does not increase the yield and reduces the R-value. A certain amount of phosphate is, of course, essential, but variations in this nutrient have not been found to produce pronounced effects. On the other hand, the effects of potassium are very pronounced. Increased amounts result in decided augmentation of both yields and R-values. Some of the highest yields combined with the highest R-values have been obtained with cultures high in potassium. These experiments have not yet been concluded, so that it is impossible to say how high the R-values can be carried by further increases in potassium content.

Originally it was planned to carry out measurements of the rate of photosynthesis and determinations of the ratios of carbon dioxide absorbed and oxygen evolved in conjunction with these investigations. Unfortunately, because of the war, it has not been possible to carry out this part of the program. As a consequence, it is impossible to give a rational interpretation of the results obtained with variations in the light factor in these culture experiments. The results are, however, in themselves of considerable interest. With 5 per cent carbon dioxide in air or in nitrogen, both yields and R-values increase in cultures raised with higher light intensities. Above about 680 foot-candles, increase in light

intensity results in no further increase in either yields or R-values. The latter increase with the length of time of illumination. Approximately, yields and R-values are a product of intensity and length of illumination, that is, of lumen hours. Comparing the same periods of illumination in intermittent and in continuous light, the yields and R-values are slightly higher in continuous light. There was no significant difference in the R-values between cultures which were harvested after a period of illumination and those which had been kept in the dark for periods of 12 to 48 hours before harvesting. Nor do the cultures, after attaining full growth, appear to change appreciably in composition, when kept free from bacterial contamination, during a period of 16 days in the dark.

The fact is again stressed that variations in any single nutrient element may result in complex reactions, including changes in the pH of the medium, so that their interpretation on metabolic principles can be accomplished only on the basis of more extensive analysis. It has, however, already been possible to discover culture conditions which result in products of very materially different composition from those encountered growing under natural conditions, and to alter the gross composition of the organisms at will to a considerable extent and in a satisfactorily reproducible manner.

#### VITAMINS IN ALGAE

Because certain algae can be grown so rapidly and for their culture require only air, light, and simple mineral nutrients, it seemed possible that, under emergency conditions, these organisms might provide a single natural source of a number of vitamins. A series of vitamin determinations, by chemical means, was carried out principally on fresh *Chlorella* and on some preserved in different ways. An effort was

also made to ascertain to what extent the vitamin content of this alga was influenced by the different environmental conditions under which it was cultured. The carotene (provitamin A) was determined by Drs. Strain and Manning; vitamin C was determined by Dr. Smith; and Dr. Manning made some determinations of riboflavin, but the latter work was interrupted by his being called to other duties connected with the war.

The carotene content of several species of algae was found to vary greatly. Two species of brown algae yielded 0.016 to 0.033 mg. carotene per gram of fresh algal material; four species of diatoms, 0.014 to 0.050 mg.; a dinoflagellate, *Peridinium cinctum*, 0.107 mg. These values are somewhat smaller than those reported for carotene obtained from leaves of higher plants.

The amount of carotene contained in *Chlorella pyrenoidosa* varied greatly with the conditions under which the cells were grown. Cells grown in continuous illumination of relatively high intensity contained as little as 0.01 mg. of carotene per gram of fresh cells, whereas those grown in low light intensities contained 0.122 to 0.29 mg.

The vitamin C determinations were made by the 2,6-dichlorophenolindophenol method. The amount of this vitamin in *Chlorella* was found to vary from about 0.3 to 0.6 mg. per gram of fresh cells. These values are about the same as those which have been found for a number of marine algae. About the same percentage of vitamin C is contained in fresh *Chlorella* as in lemon juice, one of the well recognized sources of this vitamin.

Although the losses in carotene (and presumably in riboflavin) when the algal material was preserved by various methods were relatively small, it has not been possible to devise a satisfactory means of convenient storage without material losses in

vitamin C content. Drying the cells in vacuum resulted in a loss of 30 to 50 per cent of the ascorbic acid. Nor was it possible to reduce this loss by removing the oxygen from the cells before drying in vacuum, or by blanching before drying. Even greater losses of vitamin C, amounting to about 80 per cent, were caused by sterilization of the algal material after it had been sealed in evacuated tubes.

#### THE PHOTOSYNTHATE IN SUNFLOWER LEAVES

In order that clear interpretation of the mechanism of photosynthesis may be achieved, there is great need for more precise information concerning the specific substances which are synthesized. Dr. Smith has continued his investigations on the nature of the substances produced directly by photosynthesis in sunflower leaves.

The criterion used to judge whether a particular substance arises from photosynthesis is whether or not that substance increases in amount during short periods of illumination and carbon dioxide absorption. This criterion becomes more sound the more completely the carbon absorbed as carbon dioxide during photosynthesis can be accounted for by an equivalent increase in specific organic substances.

It had long been known that the most noticeable increases in organic matter during photosynthesis occurred in the carbohydrate content. How nearly all of the absorbed carbon could be accounted for as carbohydrate was still uncertain.

The initial report on this research was made last year. It showed that a very large proportion of the carbon dioxide photosynthetically absorbed by sunflower leaves could be accounted for by the amount of carbohydrate synthesized. The proportion was so large as to indicate that under the proper experimental conditions

the carbohydrate accumulated would equal the carbon dioxide taken in. Experiments carried out during the past year have demonstrated that the agreement is almost quantitative, 98.7 per cent of the carbon absorbed being recovered as carbohydrate. To achieve this high degree of correspondence, the experiments were carried out at 10° C. instead of at 20°, the temperature at which the earlier experiments were conducted.

From the observations made thus far it may be concluded that the specific substances accumulated as a result of photosynthesis by sunflower leaves are carbohydrates. Although the experimental data indicate that under certain conditions all the carbon assimilated can be accounted for as increase in carbohydrate, the experimental error of recovery is great enough to allow for small increases in the amounts of other substances. To establish whether or not these occur will require exceedingly sensitive tests.

After it had been demonstrated that carbohydrates comprise the specific substances accumulated during photosynthesis, determinations were made of the amounts of the different carbohydrates formed by the assimilation of various amounts of carbon dioxide. As the amount of carbon dioxide assimilated increases, the percentage of the carbon dioxide recovered as carbohydrate apparently passes through a maximum. In view of the probable deviations in the results, however, it is possible that the percentage recovery may remain constant over the range investigated. Until one of these alternative possibilities has been established no valid deductions can be drawn from these data, because these alternative trends lead to quite contradictory conclusions. The maximum amount of carbon recovered under these conditions (temperature 20° C. and progressively increasing amounts of carbon

photosynthesized) was  $96.7 \pm 2.7$  per cent of the carbon absorbed.

The proportion of the assimilated carbon recovered in the sucrose fraction progressively decreases as the amount of assimilated carbon dioxide increases. Conversely, the proportion found in the monosaccharide fraction progressively increases. In fact, the sums of the percentages recovered in these two fractions are almost constant,  $61.1 \pm 1.0$  per cent. Likewise, the percentages recovered in the starch fraction remain nearly constant,  $29.6 \pm 1.6$  per cent. These facts suggest that starch and sucrose are formed simultaneously in side-by-side reactions and that sucrose is further transformed into monosaccharide. The latter supposition may be erroneous, for it is possible that the monosaccharide present in the leaf may be converted into sucrose by illumination of the leaf. Such a transformation would account for the trends noted in the sucrose and monosaccharide fractions.

Starch, sucrose, and glucose have each been proposed as being the primary carbohydrate formed in photosynthesis. The results reported here do not give an unequivocal answer to this question, but they suggest that perhaps more than one of the carbohydrates may arise simultaneously.

The residue fraction (that portion of the leaf remaining after extraction with 80 per cent ethanol and with hot water, and hydrolysis with dilute acid) is increased by treatment of the leaf with carbon dioxide in the dark. On illumination of the leaf, this fraction decreases progressively as the amount of carbon assimilated through photosynthesis increases. This decrease in the residue is reflected in a steady decline in the percentages of total carbon recovered. Because of lack of sufficient data, no well founded interpretation of the behavior of this fraction during photosynthesis can be attempted at the present time.

The increases in the other carbohydrate fractions constituted only small portions of the total gains in carbohydrate, and no significant trends in the amounts of increase were apparent.

A rigorous treatment of the kinetics of carbohydrate formation and transformation should include a consideration of the total concentrations of the various carbohydrates contained in the leaf. So far the attempts made to discover a relation between the amount of any one of the carbohydrates synthesized during photosynthesis and the amounts of others present in the leaf at the beginning of the photosynthesis period have failed. It is possible that the photosynthetic reaction is so localized in the leaf that the increase in any carbohydrate during short periods of photosynthesis is not appreciably related to the total amount of any carbohydrate in the leaf, but is related only to a part confined within some specialized unit.

Changes in conditions of photosynthesis, for example lowering the temperature and increasing the amount of photosynthesis, have been found to change the proportions of the different carbohydrates formed. It may be that greater variations in experimental conditions might even alter the basic nature of the products.

It was hoped that alternative mechanisms of carbon dioxide utilization, already pointed out, could be examined by use of long-life radioactive carbon,  $C^{14}$ , prepared by means of the Stanford University cyclotron. Though experiments showed that irradiation of ammonium nitrate by neutrons from this instrument formed  $C^{14}$ , the amount obtained was insufficient for the tracer experiments planned. Observations on the activity of one sample showed no change in activity over a period of seven months. We are indebted to Professor Felix Bloch, of the Physics Department, for the use of the cyclotron, and

to Mr. R. W. Williams, of the Chemistry Department, for making the activity measurements.

#### IMPROVED METHODS OF PIGMENT ANALYSIS

The impact of war with its insistent demands for new methods of production, preservation, storage, and shipment of plant material to be used as food for man and animals has prompted us to report several improved analytical techniques that were developed in the course of our investigations of the pigments of plants. These methodological advances have facilitated analysis of the complex mixtures of the organic substances found in plant material. They show promise of application in other fields of chemical and biochemical investigation.

Estimation of carotene (provitamin A), now widely used as a test of the quality of many preserved plant products, may be accomplished quickly and conveniently by a procedure developed by Dr. Strain, for the analysis of algal pigments. The pigments are extracted from fresh or freshly blanched plant material with acetone, methanol, or ethanol. If the material is a dried product, it is first hydrated with a little distilled water, and the pigments are then removed with the organic solvents. The solution of the extracted pigments is drawn through a filter of heat-treated siliceous earth (Filter Aid 501) into a spherical flask with a long neck, from which all the solvent is evaporated at reduced pressure and at a temperature not above  $40^{\circ}$  C. The residual pigments are then dissolved in a little petroleum ether, which is also evaporated at reduced pressure. The residual pigments are again dissolved in petroleum ether, and the solution is again drawn through an adsorption column of the same adsorbent. Under these conditions, the carotene, which is weakly adsorbed, is carried rapidly through

the column. Continued washing of the column with fresh petroleum ether carries all the carotene into the percolate, where the amount of this pigment is estimated by colorimetric or spectrophotometric methods.

Complete resolution of the complex mixtures of pigments found in various green plants has been effected only through use of the sensitive and specific chromatographic adsorption columns. Additional observations concerning the effect of various conditions on the separation of leaf pigments in the columns have now led to conclusions that may be of great benefit to those using this method in other fields, and on an industrial scale. For example, the relative positions of pigments adsorbed in the columns depend on the nature of the adsorbent and the solvent. Changes in either the solvent or the adsorbent may reverse the relative adsorbabilities of the pigments. This changes the relative rates at which the pigments move through the adsorption column and may change their relative positions. It follows that if, with a given adsorbent, one solvent causes a pair of substances to be adsorbed in one sequence, and another solvent causes them to be adsorbed in the inverse order, there should be at least one mixture of the two solvents that will not effect a separation of the two adsorbed compounds. This emphasizes the fact that determination of the homogeneity of chemical substances and comparison of materials suspected of being identical will be most effective when various solvents are used with different adsorbents.

Utilization of the chromatographic adsorption method for the preparation of substances on a large scale involves the consumption of enormous quantities of adsorbent relative to the amount of materials separated in the columns. This disadvantage may be overcome under certain

conditions through use of a finely dispersed liquid as the adsorption agent. For example, it was observed that some of the algal pigments when dissolved in petroleum ether were strongly adsorbed on the surface of the droplets of water. When the small droplets of water were permitted to fall through the petroleum ether solution of the plant pigments contained in a long, narrow tube, certain pigments were removed from the solution by the droplets and carried to the bottom of the tube. There they were deposited as a distinct phase at the water surface by the coalescing droplets. In this way the strongly adsorbed pigments were removed from the weakly adsorbed ones. With extracts of leaves, strongly adsorbed xanthophylls were removed from the weakly adsorbed chlorophylls and carotenes. With extracts of diatoms, brown algae, and dinoflagellates, the strongly adsorbed xanthophylls and chlorophyll *c* were removed from the chlorophyll *a* and carotene.

This procedure shows promise of being applicable to the separation and purification of some important technical products. Stearic acid is rapidly removed from fats (olive oil) dissolved in petroleum ether when droplets of water buffered with phosphate to pH 8 are allowed to fall through the solution. By minor modifications of the apparatus, this procedure could be made continuous in its operation.

#### NEW SOURCES OF CIS-LYCOPENE

Correlation of the properties of the carotenoid pigments and postulations regarding their possible reactions and functions in the plant depend, to a considerable extent, upon knowledge of the various kinds or types of these pigments. Some members of this group occur in very small quantities in a few sources; hence, they are difficult to obtain in quantity sufficient for chemical and physical examination. Dis-

covery of rich sources of these pigments provides substantial aid to investigators in this complicated field of research. Convenient and abundant sources of the very labile isomer of lycopene, the so-called *cis*-lycopene, hitherto obtainable with diffi-

culty, have now been found by Dr. Strain. These sources are the red fruits or berries of *Arum orientale* and of *Dracunculus vulgaris* (*Arum Dracunculus*), lilies belonging to the Araceae, the jack-in-the-pulpit family.

## EXPERIMENTAL TAXONOMY

JENS CLAUSEN, DAVID D. KECK, AND WILLIAM M. HIESEY

The experiments on plant relationships have shown that many small and gradual steps are involved in the differentiation of the natural units, from the local population to the genus. The higher of these biosystematic units are separated from one another by more distinct genetic barriers than the lower. One finds natural units on different levels of separation, but certain levels represent significant evolutionary starting points. One of the more important of these levels is reached when a group of plants has become so mature that the entire set of chromosomes, rather than the individual gene, becomes the evolutionary building unit.

At this evolutionary level distinct cenospecies have differentiated. When higher plants have reached this stage, new species may rise abruptly through the addition of entire sets of chromosomes of old species. This process is known as amphiploidy (amphidiploidy). The origination of three new amphiploid Madiinae in this laboratory prompted an inquiry into the requirements for successful amphiploidy. Principles of general importance were revealed that elucidate the relationships between natural units on the highest level that can be studied experimentally—that of distinct but related cenospecies.

This rounds out a formulation of the principles governing the degrees of biosystematic relationship, the lower levels of which were discussed in the last three Year Books.

Amphiploidy has been a highly important mechanism in plants, because many groups have followed this method of speciation, pyramiding their chromosome numbers in progressively higher series to form new species. The mechanism of amphiploidy has various patterns, and the success of new species that arise by it hinges on many circumstances.

With the three thoroughly analyzed cases of amphiploidy in the Madiinae as a background, an analysis has been made of many well documented cases reported in the literature. The objectives have been to determine the principles that govern the production of amphiploids, and the criteria for their success when they appear in nature. The results of this investigation, together with an outline of the biosystematic principles, have been incorporated in a monograph, the manuscript for which is now ready for publication.

This investigation has answered questions regarding the evolutionary pattern common to many genera of plants, and is of further significance because the controlled production of amphiploids is certain to become of increasing economic importance. The usefulness of amphiploids lies in the fact that they combine the heredities of other species and represent new, often superior combinations. Their genetic qualities are changed, and so are their physiological qualities.

In order to understand the sudden appearance of amphiploids, one must bear

in mind the organization of plants into natural units of different degrees of complexity. The existence of these units, in graded series from simple to complex, has been amply demonstrated by an abundance of experimental data.

### THE BIOSYSTEMATIC UNITS

The first important natural unit above the level of the local population is the *ecotype*. It is that component of the species which is genetically and physiologically adapted to one of the major environments occupied by the species as a whole. A widespread species may have a number of such ecotypes, kept distinct by the selective action of the environment, but genetically capable of free interbreeding where they meet.

The biosystematic unit on the next level of complexity above the ecotype is the *ecospecies*. Each ecospecies has evolved a separate genetic system that is balanced both internally and externally. The intricacy of these balances is such that genes of related systems cannot be freely interchanged without seriously impairing the ensuing development of the offspring. In other words, genetic barriers are always interposed between ecospecies. These barriers are carried along by the species wherever it migrates, insuring it a greater permanency than that of the ecotype.

Species entirely unable to exchange genes through hybridization belong to different *cenospecies*. Their genetic balances have become so unlike that even a very limited exchange between their chromosome sets is lethal. A cenospecies may consist of from one to many ecospecies capable of limited gene exchange.

Some distinct cenospecies are still enough related to be able to form sterile hybrids. Such cenospecies belong to one *comparium*. If they are unable to produce even sterile hybrids, they belong to different compara.

Consequently, the comparium becomes the largest natural unit which is subject to experimental analysis.

The ecotype is frequently the counterpart of the geographic subspecies, and the ecospecies approaches the species of the moderately conservative taxonomist. The cenospecies approximates the level of the section in most genera, but in some cases it may equal the entire genus. In complex groups the comparium frequently corresponds to the genus, but there are also examples of several adjacent genera composing one comparium, as, for instance, the wheat allies in the genera *Triticum*, *Aegilops*, *Agropyron*, *Haynaldia*, *Secale*, and *Elymus*.

### EVOLUTIONARY SEQUENCES

The four kinds of biosystematic unit just described represent important evolutionary nodes, but they are connected by many intermediate steps. The ecotype is at the evolutionary level where fitness to more than one major environment evolves. The ecospecies is at that level at which separate units arise through constitutional barriers to successful interbreeding. Beyond the level of the cenospecies gene exchange is no longer possible, although an addition of all the chromosomes of two cenospecies of one comparium is still possible through amphiploidy. The comparium marks the limit for even this event in evolution, for distinct compara have to depend on their own gene resources.

Evolution may be said to be reticulate in pattern from the level of the ecotype to that of the comparium, but beyond that level it becomes exclusively forked in type. The comparium therefore represents a very important node in the evolutionary process.

The study of hundreds of different hybrids between units of many degrees of relationship suggests that one kind of biosystematic unit may evolve from another

in successive order. The machinery for this development is provided by the processes of mutation, recombination, and selection; and the materials come from the supply of genes within the individual, or the natural unit. As the mutation process supplies new raw materials, or genes, the recombining processes repattern them, and the selective processes eliminate the unfit from the resultant new products.

Below the level of the ecospecies the most important evolutionary unit is the gene, but above the level of the cenospecies it becomes the genome. The genome is the sum of all the genes in the sex cells of a species, and is represented by the haploid set of chromosomes. When amphiploidy occurs, the retention of unbroken parental genomes is necessary for success. Between the ecospecies and the cenospecies levels, the genome evolves by the increasing interdependence of chromosomes operating in blocks, rather than as individual genes or chromosomes.

Because the comparium is the sum of all its subordinate units, many different kinds of comparium exist. The columbine genus, *Aquilegia*, is among the simplest and most flexible comparia. It has very few and but slightly separated ecospecies, but each contains many ecotypes. The majority of its described species are actually but ecotypes or groups of ecotypes, and all the biological units have remained diploid. Comparia of this kind are very adaptable to changing conditions, for they have virtually no barriers to gene interchange, and are able to inhabit areas with widely contrasting climates. The section *Drymocallis* of *Potentilla*, with *P. glandulosa* and its allies, is another example of a climatically very adaptable comparium consisting primarily of ecotypes that have remained diploid.

At the opposite extreme of the evolutionary succession one finds the monotypic

comparium, as represented by the nearly extinct maidenhair tree, *Ginkgo biloba*, which at present probably consists of only one ecotype. The fossil record discloses a circumboreal distribution for *Ginkgo* in earlier times, making it virtually certain that many ecotypes, and probably also ecospecies, existed to enable it to inhabit these different climates.

Somewhere between these extremes are the comparia that are most complex in structure, namely, those that contain several cenospecies well differentiated into ecospecies and ecotypes. Such a comparium is probably in its most active and expansive stage of development, for gene interchanges can repattern the ecotypes, and, to a certain extent, the ecospecies also. These changes can be incorporated in amphiploids that arise between members of its cenospecies. Many of our most important crop plants are members of such comparia; for example, wheat, cotton, tobacco, cabbage, etc. And the most complex groups of wild plants that show both aggressive distribution and much intergradation are also largely comparia of this kind, as exemplified by the *Artemisia vulgaris* complex of North America. The genus *Layia*, reviewed in Year Book No. 40, pp. 162-168, approaches this condition, although it has developed only one wild amphiploid species.

#### SUCCESS OR FAILURE OF AMPHIPLOIDS

The success or failure of amphiploids and other species is determined by the same factors. All the genes of the amphiploid must work together in such a way as to insure a harmonious development, and the hereditary mechanism must be able to transmit the balanced gene combination to the descendants. This conclusion was reached through studies on amphiploids that had arisen in the Ma-



diinae, and was confirmed by other amphiploids on record.

The three amphiploids synthesized in the Madiinae were *Madia nutrammii*,  $n=17$  (from *M. nutans* (Greene) Keck,  $n=9$ ,  $\times$  *M. Rammii* Greene,  $n=8$ ); *Madia citrigracilis* Keck,  $n=24$  (from *M. gracilis* (Sm.) Keck,  $n=16$ ,  $\times$  *M. citriodora* Greene,  $n=8$ ); and *Layia pentaglossa*,  $n=15$  (from *L. pentachaeta* Gray,  $n=8$ ,  $\times$  *L. platyglossa* (F. et M.) Gray,  $n=7$ ). The synthesis of *Madia citrigracilis* was attempted in order to duplicate a native species suspected of having arisen through amphiploidy and of having this parentage. The synthesized and the natural products are very similar. The production of these three amphiploids was reported in Year Books Nos. 39 and 40.

All three amphiploids arose from sterile  $F_1$  hybrids without chemical or physical treatment, and therefore are indicative of what can happen in the wild. In all three  $F_1$  hybrids the parental chromosomes were essentially unpaired, and often failed to disjoin during meiosis, thereby producing diploid gametes that contained all the chromosomes from both parents. This provided a mechanism for amphiploidy.

The two *Madia* hybrids produced successful amphiploids, which resembled the  $F_1$  and remained constant in later generations. The *Layia* amphiploid, however, showed interspecific segregation in spite of the fact that the parental chromosomes were not homologous, and it finally became so sterile that it could not be continued further. The morphological constancy of the two *Madia* amphiploids indicates that no interchange of genes took place between their parental genomes. On the other hand, the distinct interspecific recombinations in the second and third generations of the *Layia* indicated that such interchanges had occurred here.

It has been widely assumed that an

amphiploid is successful in inverse proportion to the degree of homology that exists between the chromosomes of its parents. This assumption proves to be only partly true, for other determining factors are of greater importance. For instance, the doubling of the chromosomes in intraspecific hybrids has no deleterious effect even though they are homologous, for the parent genomes are so alike that their genes are freely interchangeable. The resulting autoploid is therefore ordinarily successful. On the other hand, doubling the non-homologous sets of a hybrid between remotely related species does not guarantee a successful amphiploid, for during the irregular formation of sex cells in such hybrids fatal chromosome exchanges may take place. If the parents are very different, even slight interchanges may be lethal.

The two conditions necessary for the production of a successful amphiploid are: first, that the genomes of its parents interact to insure a harmonious and vigorous development of the  $F_1$  hybrid; and, second, that the successful initial balance be preserved through succeeding generations. This is most likely to materialize if the parents have nonhomologous chromosomes, precluding intergenomal pairing. In other words, the parents should be closely enough related to be able to produce a vigorous  $F_1$  hybrid, but remotely enough so that the balance between their combined genomes can be perpetuated.

In terms of biosystematic units, an amphiploid is therefore most likely to succeed if its parents belong to distinct cenospecies of the same comparium. The conditions under which amphiploidy can take place are limited by this requirement, but determined by the maturity of the comparium. The columbines, for example, are too immature in their evolutionary development for successful amphiploidy,

whereas *Ginkgo* probably passed the stage millions of years ago, for all its close relatives are extinct.

In reviewing the literature on amphiploidy, one finds examples of both stable and unstable combinations, and in the more thoroughly documented cases, causes for these differences can be traced to the factors mentioned. As would be expected, the more unstable types occur only as garden products (for they would be rapidly eliminated in the wild), but the stable amphiploids arise either in the garden or in nature or, occasionally, in both.

*Amphiploids versus autopoloids.* A classification of the best-known instances of added genomes was attempted on biosystematic principles. It was soon apparent that the stable combinations could be placed in two successful classes depending on the degree of relationship between their parents: (1) those that arose from hybrids between distinct or nearly distinct cenospecies, or amphiploids in the strict sense, and (2) those that arose within one ecospecies, or autopoloids in the wide sense. Between these extremes occur amphiploids between parents of intermediate relationship, that is, between distinct ecospecies of one cenospecies. Most of these represent unstable combinations, for their parental genomes are not sufficiently alike to be freely interchangeable, but are too homologous to prevent interchange after doubling. The nuclear processes that tend to perpetuate a given combination and those that tend to break it up are, however, so delicately balanced that in marginal cases gametic elimination of occasional unfit combinations may compensate for too close a chromosome homology. Therefore, when the parents belong to distinct ecospecies of one cenospecies, the success or failure of their amphiploids cannot be safely predicted.

Amphiploids arise by the addition of

the chromosomes of different species, and the parents may have either the same or different chromosome numbers. If the basic chromosome sets of the parents have the same number, amphiploids following an arithmetical progression may result from their addition in various combinations (for example,  $n=8, 16, 24, 32$ ). If the basic chromosome sets differ in number but are not polyploid, the amphiploids will be dysploid like the parents. This is exemplified by the cabbage comparium (*Brassica*, *Raphanus*, and *Sinapis*), where the species on the diploid level have 8, 9, or 10 pairs of chromosomes, their natural amphiploids on the tetraploid level have 17, 18, or 19 pairs, and two newly reported amphiploids represent the rudimentary hexaploid level, with 27 and 29 pairs.

Autopoloids arise either from a non-hybrid individual or by doubling of the chromosomes in an intraspecific hybrid. Since such parents have the same chromosome number, the autopoloids are also polyploids, but their chromosomes usually follow a geometric progression (for example,  $n=8, 16, 32, 64$ ).

The biologist dealing with natural groups of plants may find cases of both autopoloidy and amphiploidy in the same genus or comparium, one often superimposed upon the other. Such combinations are found in complex genera like *Galium*, *Tradescantia*, and *Zauschneria*. Much of the taxonomic complexity that seemed so hopeless in these groups becomes much clarified when they are analyzed in terms of the genomes of their basic diploid species combined by amphiploidy and autopoloidy.

*Ecologic relations.* Amphiploids frequently combine the genomes of species native in different climates. As a consequence they are able to invade habitats from which their parents are excluded by

natural selection, and they are often more adaptable than either parent. Thus, amphiploidy extends the range which the forms of a comparium may occupy. The cultivated timothy, *Phleum pratense* L., for example, is an amphiploid that combines the genomes of *P. alpinum* L., an alpine and arctic species of moist situations, and *P. nodosum* L., of dry, lowland situations. It grows spontaneously in fairly moist lowlands, but is more adaptable than either parent and competes successfully with both.

Ecologically and taxonomically the amphiploid reacts as an interspecific  $F_1$  hybrid that has become constant. The observations on the general adaptability of amphiploids are therefore confirmed by those on  $F_1$  hybrids between lowland and alpine ecotypes of *Potentilla glandulosa* Lindl. In the transplant experiments these have a wider range of tolerance for different environments than do their parents. This principle may be of importance in the breeding of economic plants to fit different climates.

Each chromosome level above the diploid makes new genome additions possible, so that in many genera almost all the diploid species may be interlinked genetically via the superstructure of amphiploids and autopoloids in the higher levels. The character of the superstructure is determined by the diploid species, whose genomes are the building units that give the whole its essential attributes. The various units of such a complex usually are found to occupy different ecological niches.

*The Madia gracilis complex.* During the study of experimental material for the publication on amphiploidy, it was discovered that what had been taken for a single species, *Madia gracilis*, is in fact a polyploid complex. Fifty-eight populations from localities in the three Pacific coast

states were investigated and the following facts uncovered.

A rare diploid species with 8 pairs of chromosomes occupies a few scattered localities in the dry foothills of the Sierra Nevada. This form is morphologically distinguishable from the others and has been given the name *M. subspicata*. This nearly extinct form is probably a relict of a once more common species and may be an important link in the evolution of this complex.

The great bulk of the material occurring below 4500 feet altitude is tetraploid ( $n=16$ ) and is typical *Madia gracilis*. It is very unlikely that this is an autopoloid derivative of *subspicata*, for in hybrids with other species its 16 chromosomes do not pair inter se, but remain single. Tetraploid *M. gracilis* is more probably a very old amphiploid, of which no more than one possible ancestor is known.

Above 4500 feet elevation a hexaploid form replaces tetraploid *gracilis*. It appears to have a wide distribution at higher altitudes, but is morphologically indistinguishable from the tetraploid, although it differs perceptibly in ecologic reactions. The fact that its chromosome number is 24, and not 32, points to the conclusion that it arose as an amphiploid between tetraploid *gracilis* and probably *subspicata*, rather than as an autopoloid.

In northeastern California a fourth member of this polyploid complex, the narrowly endemic, 24-chromosome *M. citrigracilis*, forms an island between the two forms of *gracilis*. The suspected origin of this form has been verified by its synthesis as an amphiploid between tetraploid *gracilis* and the 8-chromosome *M. citriodora*, a native of the region. This connection brings the latter species into the complex as its fifth member. The relations observed in this group, which is but a part of the cenospecies *M. sativa*,

parallel those found in other complex groups of plants.

*Maturation of the comparium.* The initiation of amphiploidy within a mature comparium tends to rejuvenate it. A species created through this process may be able to hybridize to some extent with its parents, which previously were effectively barred from exchanging genes with each other. If even a minor amount of gene migration takes place through the medium of the amphiploid, a revitalization occurs in what was rapidly becoming a static line of development.

After a comparium has exploited the possibilities of differentiation into ecotypes, ecospecies, and cenospecies on the diploid level, and then has recombined species, where possible, through amphiploidy, autopolyploidy, or both, it may still show a new flare of rejuvenated diversity through apomixis. This device for asexual reproduction circumvents the exacting cytological requirements for sexual propagation, permitting all sorts of hybrid derivatives to be preserved. Apomixis probably represents the last evolutionary surge that a group experiences in the course of its history, so that groups showing this characteristic may generally be regarded as very mature. Apomictic species are usually highly polyploid, apparently having passed earlier through the stages of genome addition by means of amphiploidy and autopolyploidy.

The study of the circumstances that lead to amphiploidy calls attention to basic facts concerning plant relationships that elucidate the origin of much of the otherwise perplexing biological variation. The importance of the various biosystematic elements in the evolutionary history of a group becomes evident, and the complexity in so many genera assumes new meaning, as these are found to be but

the logical expressions of the operation of fairly simple laws.

#### INVESTIGATIONS ON RANGE AND FORAGE GRASSES

The biosystematic principles that furnish a key to the understanding of the differentiation in living things have wide application in problems of both purely scientific and practical interest. Plant breeding, which aims to improve crops for given conditions and is essentially a problem of creating adapted new forms, should follow the basic laws that govern natural evolution. Therefore, before the breeding program for a group of plants is mapped, their degree of evolutionary maturity should be known. Several agronomically important genera of grasses show many of the complex features of comparia in the expansive and mature stages of development, with series of climatic ecotypes, ecospecies, and cenospecies on the diploid level, as well as amphiploidy and autopolyploidy at higher levels of chromosome number, and even apomixis or asexual propagation.

One of the vital needs of the country is for improved range grasses to increase food production and soil conservation. Ordinary methods of plant breeding are slow, but there are certain short cuts applicable to plants that have reached the evolutionary levels where amphiploidy and apomixis develop, and where the genome, rather than the gene, becomes the basic evolutionary unit. By taking advantage of the constancy of the offspring in apomictic and amphiploid plants, it may be possible to preserve the vigor and the new combinations of first-generation hybrids between even rather remotely related species.

A beginning has been made at this laboratory in the breeding of forage grasses by utilizing economically impor-

tant forms of the genus *Poa*, the blue-grasses. These experiments are being conducted in cooperation with the Soil Conservation Service of the U. S. Department of Agriculture, which has supplied breeding stocks from their valuable collections assembled at the Regional Nursery at Pullman, Washington. Mr. J. H. Christ, director of the Pacific Division, and Dr. A. L. Hafenrichter, in charge of the Nursery Division, have extended every aid toward the furthering of this program.

Drs. Keck and Hiesey made detailed studies on the materials at Pullman in June, when the grasses were in their best stage of development. The grasses in this collection represent an important sampling of our national resources, because they are selected and tested strains native to the semiarid regions of the Pacific Northwest. Of no less importance is the fact that the native habitat of each strain is known, and exact records are available on the performance of most of them for a period of years at several regional nurseries.

A few crossings between species of different sections of *Poa* were attempted during 1943, and a cytological investigation of a number of important forms is under way. More extensive crossings are being planned for 1944, and the work is also to be extended to the wheat grasses, of the genus *Agropyron*. In addition to the forms from the Pacific Northwest, a more southern series of strains is being collected along our station transect across central California. Important forms occur here from the Coast Ranges to alpine habitats in the Sierra Nevada.

A few basic principles are to be followed in this program. The inheritances of ecotypes of remotely related species native to contrasting climates should be combined to produce constant hybrids fitted to intermediate environments. This will mean, for instance, the crossing of forms

from high latitudes with those from low latitudes, and, similarly, the combining of high-altitude with low-altitude plants, of Coast Range with interior types, and of meadow forms with those native to dry, sandy localities. A program following these principles should of course also utilize the best strains available.

Experience has shown that an endemic species with no close relatives is usually less adaptable to different environments than an equally specialized ecotype from the same environment belonging to a species of wide distribution. For this reason, members of widely distributed species complexes should be utilized in the crossings.

Several simplifications in technique are possible in a program of breeding by the addition of whole genomes rather than by an exchange between genomes. Also, the opportunity is afforded of tapping reservoirs of genes that have not previously been used for breeding purposes. Plants that succeed under alpine or desert conditions have superior characteristics for many purposes, but they do not thrive in climates suitable for agriculture. By combining their genomes with those of plants from opposite extremes, new forms adapted for agricultural climates may be obtained, and by similar methods genomes of value in producing types suitable for marginal lands may be obtained from plants of the extensive wastelands in our country.

This method should also make possible the development of certain desirable characteristics in the plants. The combination of a bunch grass with a rhizome grass, for example, might result in a type that would furnish better ground cover than either of its parents alone. Likewise, breeding for disease resistance might be somewhat simplified by introducing whole genomes of disease-resistant natural species.

Some of the most important range

grasses of the temperate zone belong to the genera *Poa* and *Agropyron*. The outstanding examples of asexual propagation, or apomixis, among the grasses are found in *Poa*. In North America this genus has developed a remarkable set of species adapted to environments from the immediate coast to the dry interior, from lowland to alpine habitats, and from arctic to southern latitudes. *Agropyron* has almost as great an ecological diversity, but it is composed of sexually propagating species with strictly polyploid chromosome numbers. Whereas *Poa* has reached the stage of apomixis and very irregular chromosome numbers, *Agropyron*, along with the other genera of the *Triticum* comparium, appears to be characterized by extensive amphiploidy. Both should be suitable for breeding by the addition of whole sets of chromosomes.

By the cooperative arrangement made with the Soil Conservation Service, we are to determine the chromosome numbers of the strains, make the crossings, test the amphiploid or apomict products for constancy, and then turn the new strains over to the Service for propagation and dissemination.

The problems involved in grass breeding are so complex that every principle governing plant relationships that has been discovered in the purely scientific investigations with wild species will find application. The climatic transplant stations at Mather and Timberline are invaluable assets in the execution of this program.

#### OTHER STUDIES

Garden cultures of both annual and perennial species have been grown to obtain data needed for rounding out the cytogenetic investigation on *Layia* and for carrying out scheduled studies on the climatic races of *Potentilla glandulosa* and *Achillea*.

Miss Marguerite Hartung has been engaged in microtechnical work in connection with the grass program and the study of amphiploids. In addition, she has assisted with the records and has undertaken a special cytological study of the nonhybrid natural strains of *Layia* that have been grown over a period of years, and also of the intraspecific  $F_1$  hybrids of that genus.

The transplant stations at Mather and Timberline were maintained through 1942 on a normal basis, all necessary records having been taken. Owing to general shortages in transportation facilities during 1943, activities at the mountain stations have been reduced to those necessary for bare maintenance.

Because of war conditions, physiological studies on climatic races begun last year have been temporarily suspended, but the plans for experimental work for future investigations along these lines are becoming increasingly mature.

#### GUEST INVESTIGATOR

From June 1942 to September 1943, Professor William E. Lawrence, of Oregon State College, Corvallis, was present as guest worker at the laboratory while on sabbatical leave from that institution. His primary objective was to become familiar with the researches conducted here on the nature of species, particularly as they apply to the field of his special interest, ecology. As projects for research, he undertook a study of the ecotypes in *Deschampsia caespitosa* (L.) Beauv.; a cytogeographic study on the distribution of *Achillea borealis* Bong. and *A. lanulosa* Nutt. in western North America; and an inquiry into the occurrence and nature of vivipary in plants and its relation to apomixis.

On the basis of his first-hand observations at Stanford, Mather, and Timberline and the records and materials supplied him,

Professor Lawrence has prepared a manuscript covering his studies on *Deschampsia caespitosa*. This species is conspicuous among the grasses because of its widespread distribution. It is circumboreal across the continents of the northern hemisphere and is also found in South America. Three climatic ecotypes representing the California transect and two from northern Europe, including Lapland, were studied, and showed very distinct reactions and behavior at the three transplant stations. Despite their racial diversity and wide distribution, all were tetraploid, with 14 pairs of chromosomes.

Although *D. caespitosa* is not viviparous in northern Europe, nearly 50 per cent of

the individuals in three strains from that region became more or less viviparous when moved 20° to 30° south to California. New plants grown from their bulb-lets were found by Professor Lawrence to have the same chromosome number as the parent plant. Viviparism in this species is therefore not accompanied by an increase in chromosome number to make it identical with its high-arctic hepta- and octoploid relative *D. alpina* (L.) R. et S., which is always viviparous. The same plants tend to become viviparous year after year. Since none are viviparous in northern Europe, and only some in California, this form of vivipary must be produced by the interreactions of heredity and environment.

## DESERT INVESTIGATIONS

FORREST SHREVE

The conditions of the past year have greatly curtailed the progress of field work on the Chihuahuan Desert project. Several areas remain which have not been explored. In them the character of the vegetation may or may not be similar to that in adjacent areas in which the physical conditions are presumably the same. Previous work has shown the strong localization of many species of plants and the occurrence of outlying colonies of species more abundant elsewhere, and these facts indicate the desirability of making collections in the previously unvisited areas.

It has been possible, however, to go forward with the study of data, observations, and materials previously obtained. Some progress has also been made in field work, through the collaboration of Mr. Robert M. Stewart, of Santa Elena, Coahuila, Mr. U. T. Waterfall, professor of botany in the Oklahoma City High School, and Dr. L. C. Hinckley, principal of the High School at Marfa, Texas. These men were able to visit critical localities sug-

gested by Dr. Johnston and to send him collections of plants made in the most favorable seasons. These collections extend our knowledge of the distribution of plants of the desert plains and the small desert mountains, and throw new light on the floristic affinities of little-known areas in northern Mexico and western Texas.

Work on the flora of the Sonoran Desert, which has been conducted by Dr. Ira L. Wiggins for several years, has been continued, and additional manuscript for the published flora has been prepared. Some of the large and difficult groups of plants have now been completed. The collection made by Dr. Wiggins and Dr. Reed C. Rollins in the summer of 1941, in previously unvisited parts of Sonora, has been studied. This has proved to be a very valuable contribution to knowledge of the Sonoran flora, revealing many northward extensions of range in the interior and a number of southward extensions on the Gulf coast between Tiburón Island and Guaymas, and also bringing to light 7

new species. These have been published by Dr. Wiggins and Dr. Rollins.

During the year Dr. Johnston has been able to give a large share of his time to preliminary work on the flora of the Chihuahuan Desert. He has organized the series of collections made by himself and the several collaborators on this project, and has studied the material in the Gray Herbarium collected in neighboring regions by early botanists. In the recent exploration particular attention has been given to northern Coahuila, where there is a great diversity in topography and physical conditions, where there proves to be an unusual assemblage of species, as well as of plant communities, and where very little collecting had previously been done. The discovery of a large number of novelties in this area has compelled Dr. Johnston to give considerable time to their study and the preparation of descriptions for publication. In this group 13 new species and varieties have been published this year. As an aid to the preparation of the flora of the Chihuahuan Desert, Dr. Johnston is now bringing together an enumeration of the plants of the State of Coahuila, which occupies an important place in this desert both geographically and floristically.

In the preparation of results of the study of Sonoran Desert vegetation, the principal recent work has been concerned with description of as much as is known of the ecological life histories of certain common plants, determination of the geographical distributions of some 100 dominant species on the basis of herbarium specimens and field notes, and assembling of all available data on the distribution of the summer and winter herbaceous ephemerals.

The object of the descriptions of life histories is to place on record all that has been learned from long observation of the plants, and in some cases from cultivation and propagation, and also to indicate

features of the plants that cannot be learned by consulting a herbarium specimen. Although these plants are mentioned many times in the descriptions of the ecological subdivisions of the Sonoran Desert, it seems desirable, for ease of reference, to place much of the information about them under individual specific headings.

Among the plants confined or nearly confined to the Sonoran Desert, over 125 species are dominant in some part of the area, and a larger number are locally dominant or infrequent. Many of these plants have been collected so seldom that existing herbarium material gives an imperfect record of their distribution. Field notes taken during the years of exploration greatly augment the records and make it possible to prepare maps showing the known areas of distribution of single species and related groups of species.

The plants now endemic to the North American Desert undoubtedly include relict species of great age, some of which formerly enjoyed a wider distribution, and also modern species which have emerged under the conditions of recent time. It is scarcely to be hoped that a close study of the present areas of distribution of the endemics can give much information about their ranges in the past. There are a few cases, however, in which the ecological life history of a plant strengthens the distributional evidence that it is a waning relict. There are also a few groups of closely related endemics whose collective distribution throws some light on the recent development and movements of the genus to which they belong. As examples of these cases may be taken the small tree *Holacantha Emoryi* and the large genus of shrubs *Franseria*.

*Holacantha* is fairly abundant in a few areas in the Gila Valley, Arizona, and in the central Mojave Desert, and is very uncommon elsewhere. It never forms pure



stands and is often represented only by isolated trees in widely separated localities. A closely related species, *H. Stewarti*, is of very limited occurrence in the Chihuahuan Desert. The seeds of *Holacantha* remain on the tree for 3 to 7 years and germinate poorly and tardily. Seedlings and young trees are rare. The growth of the tree is very slow, and its flowering is sporadic and late in the life of the tree. These features all indicate a poor adjustment to environment and corroborate the distributional evidence that *Holacantha* is a waning genus, now confined to two species.

*Franseria* is a genus of about 40 species which has its principal development in the Sonoran Desert. It is also represented on the dunes and beaches of the California coast and on the coast and mountain slopes of Peru and Chile. The members of the genus show considerable diversity in habit and habitat, although there are several cases of very closely related species. Nearly all the species are abundant and aggressive in their optimum habitats, and 5 of them are among the most common dominants in their respective parts of the Sonoran Desert. A few species are confined to unusual habitats but are abundant wherever these habitats occur. In the dominant desert species, the seeds germinate at winter temperatures. In a group of species which are infrequent or absent in the heart of the desert, the seeds germinate at summer temperatures. The ranges of these species extend from the edge of the desert far east and north into the grassland and forest.

*Franseria* embraces the largest group of congeneric endemics in the Sonoran Desert and has shown its vigor by the development of the group of dominants, which are often the commonest plants over large areas, by the development of a group requiring special conditions, by the attainment of a treelike habit in one tall

woody species, and by the appearance of a form so highly specialized in its fruit that it has been referred to a separate monotypic genus, *Acanthambrosia*.

Between these extreme examples of the endemics lie many forms which are clearly relicts, many aggressive ones which are apparently recent, and others whose status is doubtful.

A tabulation of the distribution of summer and winter herbaceous ephemerals has been made on the basis of herbarium material, published reports of occurrence, and localities recorded in field notes. Caution has been necessary in using citations from different sources, and the unevenness of the taxonomic scrutiny that has been given the many genera concerned has made it necessary to disregard varietal differences, although they are often very significant.

With few exceptions the appearance of the two groups of ephemerals is strictly confined to either the winter or the summer rainy season. The distribution of the two groups is therefore primarily controlled by the seasonal distribution of rainfall. The great number of winter ephemerals on the California coast, where there are no other native lowland herbaceous plants, falls sharply at the western edge of the desert and declines gradually from the Colorado River to the Rio Grande. The strongest representation of northern genera in the desert is found among the winter ephemerals. The entire group appears to have entered the desert during a prolonged cool and rainy period. It is particularly significant that nearly all the winter ephemerals in southern Arizona are representative of species found in coastal California or the Mojave Desert, and that there are no clearly distinct species that are confined to the region east of the Colorado River.

The summer ephemerals of the Sonoran

Desert are for the most part of wider distribution than the winter ones. A high percentage of them are common to the northern part of the Chihuahuan Desert, the desert grassland region, and the northern part of the Pacific coast thorn forest in Mexico. In this group the Compositae, Allioniaceae, Amaranthaceae, and Euphorbiaceae are the principal families represented, and among the genera are many which have a large number of representatives in central Mexico. Only a few of the summer ephemerals occur in the deserts of California, appearing after the summer rains which reach that area on rare occasions. The summer ephemerals are clearly a group derived from the regions southeast and south of the Sonoran Desert. In southern Sonora there is a very poor representation of winter ephemerals, and a few of the summer species are active in the winter. This is because the soil temperatures of winter are higher in southern Sonora than in southern Arizona.

Mr. Howard Scott Gentry, now a graduate student in the University of Michigan, spent five periods of several months in

botanical exploration of the drainage basin of the Río Mayo, in southern Sonora. This river crosses the western slopes of the Sierra Madre very close to the boundary between the Sonoran Desert and the thorn forest belt of the Mexican west coast. On account of the close relation between Mr. Gentry's work and our own investigations, he was granted the facilities of the Desert Laboratory for studying his material and preparing a report on his work. He has now published a brief description of the physical features and vegetation of the area, together with an annotated list of 1276 species and varieties of plants collected (Carnegie Institution of Washington Publication 527). The lack of previous exploration in the Mayo Valley is proved by the detection of 92 new species.

This publication helps to fill a wide gap in knowledge of the vegetation of the mountains of the west coast of Mexico. The annotated list gives data on the flowering and seasonal behavior of the plants, economic uses by the aborigines, and habitat distribution in an extremely rugged area where desert and subtropical species meet.

## PALEOBOTANY

RALPH W. CHANEY

Progress in the study of Tertiary and Cretaceous plants in the western United States has been delayed by war activities. Dr. Chaney's time has been largely occupied by administrative duties related to the war program of the University of California, but he has continued the study of Miocene collections from the John Day Basin made within recent years. Dr. Erling Dorf has been fully engaged in teaching courses assigned at Princeton University under the Army Program. His studies of

the Cretaceous floras of the Rocky Mountain area continue when time is available.

Lieutenants Harry D. MacGinitie and Daniel I. Axelrod are attached to the Army Air Force. MacGinitie is an instructor in a Bombardier Training Headquarters, and is finding limited time to carry on his investigation of the Florissant flora. Axelrod is on active duty in the South Pacific area, and is taking advantage of occasional opportunities to become acquainted with the modern vegetation there.

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# DEPARTMENT OF EMBRYOLOGY

*Baltimore, Maryland*

GEORGE W. CORNER, *Director*

Although the work of the Department of Embryology, like all other essentially peaceful activities, has been limited by the national mobilization for war, a considerable part of the program of investigation has gone forward. The collection of human embryos has received numerous additions from contributors in many different cities, including three of the second week. Preparation and study of selected choice specimens has been carried on, particularly several of the Hertig-Rock series described in Year Book No. 41. Early publication of these and other important presomite embryos will add a new chapter to the history of the human body in its earliest stages.

The work in experimental biology and the effects of hormones on the marsupial embryo has begun to yield not only extensive observational results, but also theoretical conclusions of importance. A long-term study of the development of behavior in the infant monkey has been brought to conclusion. Additions have been made to our knowledge of the structure of the ovary in two species which are yielding much valuable information, namely the rhesus monkey and the opossum. Experimental studies of the use and effects of the

sex-gland hormones have developed in several directions. All these investigations are explained below.

Owing to the absence of staff members engaged in war activities, the physiological and biophysical studies have been greatly limited.

Several lines of research involving the use of rhesus monkeys—cyclic histology of the reproductive tract, physiology of menstruation, structure of the placenta—have been carried on in a limited way. Conditions in the Pacific have greatly impeded the importation of monkeys, and the resources of the colony have therefore had to be husbanded.

The experience gained by Dr. Louis Flexner and his colleagues in research on chemical exchanges between mother and infant through the placenta, and the apparatus developed for that purpose, have been applied by Dr. Alfred Gellhorn to a medical problem of special importance in war time.

Absences and difficulties due to the war have fortunately caused only delay, without fundamental disruption, of the program of investigation, and the Department will at the close of hostilities be ready to resume work on the full scale.

## EMBRYOLOGY

### DEVELOPMENTAL HORIZONS IN HUMAN EMBRYOS

The appearance during this year of the first installment of Dr. Streeter's extensive work on developmental horizons in human embryos demands a special word of explanation to non-embryologist readers. The aim of this work, briefly stated, is to set

up a practical standard of comparison for human embryos, especially in the earlier stages, which can serve as a measure of the degree of development reached by a given embryo.

Every science aims at systematization and precise statement of its data and ultimately at expression of its results in terms

as nearly mathematical as possible. In the case of embryology, however, and especially in that branch which treats descriptively of the early growth of external form and of the internal organs, there are peculiar difficulties which have long impeded even the beginnings of quantitative formulation. As simple a first step as the arrangement of a number of embryos in the serial order of their development meets with grave obstacles. An embryo is a living thing, subject to all the variability of the life process. Its form is ever changing and is difficult to characterize except by means of pictures. Comparison of dimensions is precarious, for young embryos are very plastic and one of them may be flexed or twisted more than another of the same age. What is more, the significance or the usefulness of a given dimension changes; to cite an example, up to a certain stage the head of the human embryo is so small and so bent down that the nape of the neck is higher (so to speak) than the crown of the head, and the neck-to-rump measurement is then the best expression of the size to which the embryo has grown. After the head straightens up, however, the crown-to-rump length ("sitting height") gives the best measure of the embryo. Finally, the evaluation of human embryos that come to the laboratory is hindered by all sorts of variable factors such as pathological states, non-uniform preservation, and uncertain histories.

Every descriptive embryologist since the beginning of the science has of course found it necessary to arrange his embryos in a series based on some standard such as the age, the size, or the state of development. Because in the case of early human embryos the age is often uncertain, and the size is an unreliable guide, the investigator is forced to depend in large degree upon the apparent state of development if he wishes to gauge the status of

an embryo or to put a series of them in order. Wilhelm His made the first thorough attempt to construct a tabular norm for human embryos, in his *Anatomie menschlicher Embryonen*, of 1880-1885. In his plate a series of selected individual embryos is depicted as he arranged and numbered them in the supposed serial order of their development. The same principle was applied in the various volumes of the *Normentafeln zur Entwicklungsgeschichte der Wirbeltiere*, written by various authors under the leadership of Franz Keibel between 1897 and 1922. The method has the disadvantage that individual embryos cannot in fact be arranged in a perfect series; one specimen may be more advanced in one respect, more retarded in another, than a similar embryo. Even after an approximately serial array of pictures is prepared, in using it (for example) to date a new embryo it may prove impossible to match the specimen successfully to any one of the pictured stages.

In No. 4 of the Keibel *Normentafeln*, which deals with the rabbit, C. S. Minot took advantage of the easy breeding of that species to set up norms each of which was based on the collective evidence of three embryos chosen from the median litter of a group of the same age. Thus he introduced the rudiments of a statistical method.

Another step which was to prove useful for human embryology had been taken years before by the brilliant Francis Balfour (*The development of elasmobranch fishes*, 1876) when he assembled his embryos into a series of groups or stages (indicated by key letters) based on the comparison of many features of each specimen so that individual differences were rendered less significant. For use in comparing embryos with the standard, the method of formal stages has the further advantage that it is obviously more practicable to

match a specimen to a given stage, having a certain latitude of variation, than to one single specimen of a more numerous and more gradual series.

That the normal series of stages, pictured and described by a master embryologist, is the only practical way we have to express the degree of development of an early embryo is shown by the wide use of Ross G. Harrison's stages of the salamander *Amblystoma punctatum*, a favorite material of experimental embryologists. Without having been formally published, Harrison's plates have circulated from laboratory to laboratory until everyone who works with *Amblystoma* can make himself clear to a fellow worker about the stage of an embryo by referring to the Harrison number. Similar guides have been prepared for two or three other amphibians, and recently J. S. Nicholas has set up a series of numbered stages of the mouse embryo for use by experimental workers.

Dr. F. P. Mall, founder of this Department, was the first to attempt a classification of human embryos into formal stages. In a paper published in 1914, just before his collection was transferred to the Carnegie Department of Embryology, Mall published in the *Anatomischer Anzeiger* a brief paper on "Stages in the development of human embryos from 2 to 25 mm. long." In this document he proposed fourteen stages indicated by letters, from H to U, each stage being distinguished by the presence of certain anatomical features. Stage I, for example, begins with the appearance of an arm bud and has three pronounced branchial arches; in Stage P, the branchial arches have disappeared, the ear is well formed, and the toes are outlined. To a mathematician this may seem a crude way of constructing a scale, but it is a respectable method in biology and has its own kind of precision. Mall did not illustrate these stages, for he did not view the

grouping as final. He was well aware that he lacked sufficient specimens for his earlier stages, and he was under the necessity of reserving the letters prior to H for the presomite stages, which were then practically unknown.

In the 28 years between 1914 and 1942 the Carnegie Collection has grown so extensively that it can provide an immensely richer material for comparison than Mall had before him, and there has been a great advance in our detailed knowledge of the earlier stages, including the early somite stages, of which Mall had very few specimens, and the presomite stages, of which he had none. The present is the time, and Dr. Streeter is unquestionably the best-qualified expert, to undertake a definitive classification of human embryos in age groups.

Dr. Streeter has planned to include all stages from the earliest available, up to fetuses between 32 and 38 mm. long, the stage at which the eyelids have come together. This is about the beginning of the eighth week after ovulation. Beyond that time the rate of increment in size is large enough to provide an adequate index of relative development. It is in embryos of the first seven weeks that the external form and structural organization give more reliable information as to age than do the dimensions.

Dr. Streeter proposes to subdivide the first seven weeks of development into about twenty-five age groups, of which he originally defined twelve, as follows: I, one-celled egg; II, segmenting egg; III, free blastocyst; IV, implanting ovum; V, ovum implanted, but still avillous; VI, primitive villi, distinct yolk sac; VII, branching villi, axis of germ disk defined; VIII, Hensen's node, primitive groove; IX, neural folds, elongated notochord; X, early somites present; XI, 13 to 20 paired somites; XII, 21 to 29 paired somites. The first four of these stages are still unknown in the

human species. Stage V is now being revealed by the Hertig-Rock embryos, mentioned below, and other specimens. Stages after XII will be defined as the work progresses.

Because of the size of the undertaking, Dr. Streeter plans to issue his monograph in parts as rapidly as they are finished. He has chosen to begin with stage XI rather than earlier, largely because knowledge of the younger stages is growing and the material will be richer in the future when he works back from stage XI.

The first installment, comprising stages XI and XII, was published in volume XXX of the Contributions to Embryology, and the second, comprising stages XIII and XIV, is at the present writing almost ready for press. Each section includes photographs and diagrams of representative embryos of the given stage, with text describing the external form and the internal structure. Not only the typical characteristics of the group are noted, but also the changes due to growth during the period, and the range of variation.

The work is accompanied by tables which list the embryos of each group in the Carnegie Collection and by a list of those embryos, not only in the Collection but elsewhere in the world, which have been described in the literature. It will consist, therefore, of a descriptive atlas of early human embryology, an authoritative classification by stages, a catalogue of early embryos in the Carnegie Collection, and a guide to the world material. We are confident that its progress will be eagerly watched by embryologists everywhere.

#### HUMAN EMBRYOS OF THE SECOND WEEK

We can again report an advance in the cooperative program of study of early human embryos, carried on in conjunction with Dr. A. T. Hertig and Dr. John Rock, of Boston. Last year's report men-

tioned the specimens 8020 (believed to be  $7\frac{1}{2}$  days old) and 8094 (believed to be  $9\frac{1}{2}$  days old). During the present year the Boston collaborators, continuing their work under a renewed grant from the Carnegie Corporation, have obtained two more specimens of this age group, nos. 8155 and 8171. The older of these is intermediate between the  $9\frac{1}{2}$ -day and the  $7\frac{1}{2}$ -day specimens; the younger is much like the latter, and may be a little older or a little younger.

These two new embryos have been successfully cut into serial sections, mounted and stained by Dr. Heuser with the aid of Miss Caspari and Mr. Drane, and fully photographed by Mr. Heard and Mr. Reather. Taken together with 4 Hertig-Rock embryos previously reported and the incomplete Miller embryo, the Carnegie Collection now contains 7 normal embryos from about the 7th to about the 12th day; a truly impressive addition to the sum of human knowledge, for until a very few years ago this period of development was totally unknown so far as the human species was concerned. Each addition to the group has not only contributed its own quota of new information, but helped to distinguish those features which are common to them all from those which are individual peculiarities.

The study and description of these specimens is going on in spite of all the limitations of research in wartime. Two were published by Hertig and Rock in volume XXIX of the Carnegie Contributions to Embryology, as reported in Year Book No. 41; two more are being prepared for publication in volume XXXI; and the two newly acquired are being intensively studied.

#### AN EMBRYO OF ABOUT 19 DAYS

One more has been added this year to the series of important embryos described

in the Contributions to Embryology. This is a presomite embryo from a tubal pregnancy, estimated to be about 19 days old. The specimen is in the possession of Dr. W. C. George, of the University of North Carolina, who has studied and described it in consultation with Dr. Streeter and Dr. Heuser. The embryo is slightly more advanced than that described by Heuser in 1932 (Carnegie no. 5960).

#### A FROG WHICH HAS NO TADPOLE STAGE

The Jamaican frog *Eleutherodactylus nubicola* passes its life at a high altitude among rocks and stones, and lays its eggs in small hollows beneath the stones. Although an amphibian by relationship, it is in fact not amphibious, for the embryos develop in a relatively dry environment and not in the water. The tadpole stage is perforce completely omitted. The embryos get their oxygen directly from the air, and they develop rapidly and directly into tiny frogs. Such a remarkable adaptation of course deserves the fullest study.

Similar direct development occurs in other species of *Eleutherodactylus*, and several writers have contributed information on the subject. In recent years Dr. W. Gardner Lynn, while a member of the Department of Zoology of Johns Hopkins University, has made a thorough study of *E. nubicola*. The Department of Embryology has been able to contribute to the illustration and publication of this work.

Even the non-biological reader will be fascinated by the extraordinary pictures on plate 1 of Dr. Lynn's paper in the Contributions to Embryology, which show the change from egg to frog in about 26 days. During the embryonic development no gills at all are formed. The tail develops into a great leaflike expansion, rich in blood vessels, which apparently serves as a respiratory organ. The fore and hind limbs appear simultaneously and grow

steadily throughout the embryonic period. The central nervous system differentiates with great rapidity. The formation of the skull and the hyoid apparatus is much modified by the omission of the tadpole stage. The pharyngeal derivatives, because of the absence of gills, are easily studied and furnish clear evidence concerning the origin of the postbranchial bodies, carotid glands, and "Kiemenreste" of ordinary frogs.

#### HORMONES AND THE DEVELOPMENT OF THE REPRODUCTIVE SYSTEM

The work of Dr. R. K. Burns, Jr. on the effects of the sex-gland hormones on the embryonic reproductive system of the opossum has progressed favorably and was reported in three papers during the year. This work is based upon the fact that the young opossum is born (that is, leaves the uterus) at the extremely early age of about 13 days, and is thereafter for some weeks carried in the brood pouch of the mother. The investigator can therefore get at the embryo for purposes of experimentation at a far earlier age than in other mammals. Dr. Burns has used this advantageous situation to study the effect of the sex-gland hormones on the embryonic urinogenital system. Some of his general conclusions thus far are explained in his contributions to two biological symposia held in 1942 (see bibliography), as follows:

Because of difference in origin, developmental age, and previous differentiation, the parts of the embryonic urinogenital system in the young opossum vary widely in their reactions to estrogenic and androgenic hormones. Differences in reaction threshold exist, which may shift from one stage of development to another.

Some structures, for example the phallus, pass through three phases in their relations to hormones: an early "somatic phase," in which hormones are apparently not



concerned; an intermediate "humoral phase," in which hormones collaborate with the constitutional, genetic factors in determining the form of the structure; and a final period in which hormones no longer exert a morphogenetic effect, but continue, nevertheless, to influence growth and functional state.

For certain other structures (prostate, vagina) "critical periods" exist, during which presence or complete absence may be determined by the type of hormone administered. These critical periods may be of relatively short duration.

A constant, sex-linked difference in size (or rate of growth) is shown by most structures in their responses to hormones. The phallus of a female, for instance, cannot be developed to full male size by male hormones. This characteristic appears to be inherent in the primordium itself as one aspect of its primary conditioning. Large dosages have no power to override this difference. Though hormones may condition the form or the sex type, or even the presence or absence of a part, the size attained is influenced at all stages of development by genetic constitution.

In large quantities, crystalline hormones typically produce marked bisexuality, through their ability to stimulate certain heterotypic sex structures. Male hormones, for example, if the dose is fairly large, cause simultaneous differentiation of epididymis and vas deferens from the Wolffian duct, and oviduct and uterus from the Müllerian duct. The manner in which this nonspecific effect is exercised is still uncertain. Testosterone propionate at the proper dosage, however, is capable of acting as a sex-specific agent to a remarkable degree.

The so-called paradoxical effects of crystalline hormones on heterotypic structures, at high dosages (that is, the elicitation of female characters by male hormones and

vice versa), are apparently limited to parts having alternative manifestation, such as the Wolffian and Müllerian ducts, one of which is normally differentiated to the exclusion of the other. The mystery of these effects is greatly reduced, as Dr. Burns has shown by his experiments, if the size of dosage be taken into consideration. Just how an excessive dose elicits a heterotypic effect remains to be ascertained by experiment. It is possible (1) that the normal level of responsiveness of the tissue is overridden, or (2) that some of the excess hormone is converted in the body into chemical derivatives having different effects, or (3) that the production of other hormones elsewhere in the body is stimulated.

The work has brought out very strongly the existence of specific levels of reactivity in the various tissues of the embryo; in other words, the constitutional or genetic factors which determine growth make one organ or region more susceptible to a given hormone than another. The final result of treatment with a hormone depends on the nature of the tissues affected, as well as on the type and the dosage of the hormone.

#### ORIGIN OF THE EPITHELIUM OF THE URINOGENITAL SINUS

In volume XXX of the Contributions to Embryology Dr. Burns has published the full account of his studies on the urinogenital sinus of the embryonic opossum, mentioned in Year Book No. 40. The lining of the urinogenital sinus reacts sharply to estrogenic hormones by assuming a characteristic histological structure similar to that of the adult female, and thus can be indicated or marked, so to speak, by hormone treatment long before it would normally respond to hormone produced in the animal's own ovaries. The extent to which the sinus epithelium

participates in the formation of later stages of the urinogenital organs (neck and trigone of the bladder, sinus horns, and vagina) is thus readily followed. Dr. Burns' results suggest that stratified squamous epithelium found in the vagina, urethra, and prostatic utricle of higher forms, and under experimental or pathological conditions in the bladder and even the uterus, in all probability is derived from sinus epithelium and reaches its relatively wide distribution in the adult by spreading from the sinus region, rather than by local differentiation *in situ*. This suggests further that so-called "metaplasia" or local modification of cell types seen in the adult urinogenital system as a result of hormone treatment or pathological change may actually be due to migration of epithelia rather than to local change. The results have therefore considerable bearing on some of the problems of pathology of the urinogenital system in man, and also on theoretical questions of differentiation and growth.

#### FATE OF THE MEDULLARY CORDS

The ovary is formed as a result of two successive proliferations of cells from the germinal epithelium investing the ventral

surface of the mesonephros. The cells of the first proliferation (primary sex cords) normally are transitory and of no functional significance. The second proliferation (the future cortex) dwarfs and crowds the remnants of the primary cords to a central position in the medulla of the ovary. The nature and time of disappearance of the medullary cords has become a matter of importance because the eminent gynecological pathologist Robert Meyer has suggested that masculinizing ovarian tumors of the type known as arrhenoblastoma develop from medullary cords present atypically in the adult ovary. Dr. Thomas R. Forbes, of the Johns Hopkins Medical School, has studied the question in 55 serially sectioned ovaries of human embryos and young children, partly from the Carnegie Collection. He finds that the primary sex cords begin to regress at 150 mm. crown-rump length and usually disappear at 280 mm. They were not present at all in the 11 postnatal infants of the series. Meyer's hypothesis regarding arrhenoblastoma is of course not contradicted by these findings, but if such tumors do arise from primary sex cords, there must be exceptional ovaries in which the cords persist into postnatal life.

### PHYSIOLOGY OF THE FETUS

#### SWALLOWING AND PERISTALSIS IN UTERO

It has been demonstrated clearly by many observations and experiments that in birds before hatching and in mammalian fetuses *in utero* the gastrointestinal tract is functionally active, as evidenced by swallowing of amniotic fluid and by intestinal peristalsis. Such observations on the human are scanty but convincing. Dr. Harold Speert has now carried out systematic experiments on monkeys at known stages of pregnancy, using a method

worked out some years ago by roentgenologists. Small quantities of radiopaque substances (Diodrast, Thorotrast) are injected into the amniotic cavity through the intact abdominal wall of the mother. Corresponding amounts of the amniotic fluid are withdrawn before the injection. Subsequent radiograms show that the amniotic fluid is swallowed and passes along the gastrointestinal tract. The rate of swallowing increases and the emptying time of the fetal stomach decreases as pregnancy

progresses. Since the intestinal contents are found to become concentrated, it is obvious that water is absorbed by the fetal

intestine. No evidence was obtained that in the rhesus monkey defecation normally occurs *in utero*.

## THE REPRODUCTIVE ORGANS AND THEIR HORMONES

### CORPORA LUTEA AND CORPORA ABERRANTIA

There has been no thorough study of the retrogression and ultimate fate of the corpus luteum in the ovary in any of the lower mammals, and in the human species we have only a vague idea about such matters as the time taken by the corpus luteum to disappear from the ovary, and its structure at the various stages of retrogression. Dr. G. W. Corner undertook some years ago, at Rochester, experiments on rhesus monkeys intended to answer these questions for that species. It was hoped also that the experiments would help explain the history of the corpora aberrantia, peculiar structures of very uncertain history occurring in the ovaries of the rhesus monkey.

In a group of 5 animals showing fairly regular menstrual cycles, the ovaries were exposed by surgical exploration under anesthesia. The most recent corpora lutea were marked or "tattooed" by tiny injections of India ink just under their capsules. Careful sketches of the ovaries were made, and by transillumination in the darkened laboratory the presence and situation of solid masses (i.e., corpora lutea, etc.) were noted. By re-exploration in several subsequent cycles, and by final autopsy and microscopic examination of the ovaries, it was possible to discover what happened to the corpora lutea.

Corpora lutea of the standard type shrink gradually after their functional period is over, and become more and more distorted by adjacent structures. Their cells become contracted and laden with lipid granules. They are still recognizable after 18 weeks, but probably are not identifiable

much longer. The corpus aberrans turns out to represent simply an alternative mode of retrogression of the corpus luteum. Instead of degenerating in the fashion described above, certain corpora lutea pass (just after the menstrual flow following their formation) into a state of prolonged existence resembling that of the corpus luteum of pregnancy. They differ sufficiently, however, from standard corpora lutea of the functional stage to be readily distinguishable. As late as 15½ weeks they are still well preserved. The time of their ultimate disappearance from the ovary remains unknown.

### LIPIN AND PIGMENT IN THE CORPUS LUTEUM

Cytological studies of the corpus luteum of the rhesus monkey by Dr. I. Rossman, of the Department of Anatomy, University of Chicago, revealed so much of interest in connection with Corner's studies, just described, that Dr. Rossman was invited to publish his results simultaneously in the *Contributions to Embryology*. He finds that the retrogressing standard corpus luteum accumulates a chemically distinct substance of faint yellow color which he calls luteolipin. By observing, in suitably stained sections, the relative quantity of luteolipin and ordinary lipins, it is possible to distinguish three well defined stages in the retrogression of the corpus luteum. Dr. Rossman was able, in fact, to restrain some of Corner's specimens, the age of which was known by direct observation, and to diagnose their age correctly. His studies also agree in showing that the transition from the standard corpus to the corpus

aberrans occurs during menstruation. An outstanding feature of the transition is the loss of lipin from the granulosa elements.

#### ATYPICAL FORMS OF THE CORPUS LUTEUM

When an ovarian follicle is converted into a corpus luteum, the point of rupture normally heals over smoothly or (in some species) is marked by a small crater-like protrusion of corpus luteum tissue. As a rare abnormality, the corpus luteum may, however, be protruded or herniated to a great extent, going so far sometimes that the corpus luteum may be said to be everted. Having seen cases of eversion of the corpus luteum three times in rhesus monkeys, Dr. G. W. Corner has made an experiment aimed at producing the condition artificially. Since everyone who has studied the subject has supposed that abnormal extent of the rupture in the follicular wall is the cause of the protrusion, Dr. Corner chose a rabbit with mature follicles on the point of rupturing and under anesthesia produced (by cutting with a small knife) abnormally large rupture slits. The follicles so treated gave rise to everted corpora lutea.

The matter has some practical importance because if extreme herniation of the corpus luteum ever occurs in human patients, a surgeon unfamiliar with it might think it some sort of ovarian tumor.

In a few species of insectivores, eversion of the corpus luteum is a constant and normal event.

#### THE OVARY OF THE OPOSSUM

Dr. Pedro Martínez-Estève, during his stay in our laboratory on a Guggenheim Fellowship, was given access to Dr. C. G. Hartman's extensive collection of opossum ovaries. Since very little has been published regarding the structure of the marsupial ovary, Dr. Martínez has prepared a

general account of what he has seen in the opossum. The following points are of special interest. The cumulus is small and there is no corona radiata. The zona pellucida of the ovum is much thinner than that of eutherian ova. The first polar body is given off and the second maturation spindle formed within the ovary, as in most of the higher mammals. The corpus luteum is formed from luteinized granulosa cells. It seems to develop more rapidly than in the higher mammals, for at the age of 3 days it is already a solid body with only a small connective-tissue core. Signs of involution are seen at 10 days in the pseudopregnant animal, and at 13 days (the time of parturition) in the pregnant. The involution of the corpus luteum is not influenced by lactation.

Dr. Martínez describes two features of follicular atresia which seem not to have been mentioned previously. One is filling of the antrum folliculi with swollen cells; the other is the metamorphosis of granulosa cells into connective-tissue-like cells in follicles in an advanced stage of atresia. The interstitial tissue, which is extremely variable in amount, arises as in other mammals, from the theca interna of degenerating medium-sized follicles.

#### HISTORY OF THE OVARY

Having been invited to contribute something of historical interest to a testimonial volume in honor of Dr. Herbert McLean Evans, of the University of California, a former Research Associate of the Carnegie Institution, Dr. Corner prepared a translation of the key chapter of Regner de Graaf's famous book on the female reproductive system (*De mulierum organis generationi inservientibus*, 1672, cap. xii). In this chapter the brilliant young Dutchman published the first thorough description of the mammalian female gonad and

established the fact that this organ, like its homologue in birds, is actually an ovary. De Graaf did not, of course, identify the actual egg, for he thought that the whole Graafian follicle was the ovum. It remained for von Baer in 1827 to complete the story. De Graaf's epoch-making description has apparently been translated into modern languages only twice before. There is a Dutch version of his complete works made in 1686, and an English translation of this chapter by Robert Knox in 1848. The latter appeared in an obscure journal and is little known. Dr. Corner's new translation is accompanied by an excellent portrait of de Graaf based on an old engraving, by Mr. D. K. Winter.

#### MICRODETERMINATION OF PROGESTERONE

Before his departure to join the U. S. Army Air Force (School of Aviation Medicine), Dr. S. R. M. Reynolds was able (with the collaboration of Dr. N. Ginsburg) to complete a report on the first stage of his projected program of micro-detection of hormones concerned in reproduction. Using the ultraviolet spectrophotometer, with the aid of a physicist, Dr. Ginsburg, he found that the absorption curves for progesterone and estrogen are such that the two hormones may be measured simultaneously. The test for progesterone is characteristic for alpha, beta unsaturated ketones, and by employing suitable chemical procedures in preparing the hormone for examination, the investigator may be reasonably certain that he is dealing with  $\Delta^4$ -3 ketosteroids. The method does not distinguish between testosterone, corticosterone and related substances, androstenedione, and progesterone. At present, therefore, its usefulness is limited to experimental conditions in which it is certain or highly probable that progesterone or at least one of the  $\Delta^4$ -3 ketosteroids is present. There are many prob-

lems, however, in which the method could be usefully employed, and after the war no doubt it can be further improved.

#### EVIDENCE AGAINST A PROGESTERONE-LIKE ACTION OF ASCORBIC ACID

Ascorbic acid (vitamin C) is present in high concentration in the corpus luteum. It is also present in the uterus, where it is said to increase in amount when the corpus luteum is functional. Removal of ascorbic acid from the diet of the guinea pig is said to diminish the effects of the corpus luteum and even to cause termination of pregnancy. These facts have led certain workers to suppose that ascorbic acid is an intermediate agent in the action of the corpus luteum. An article appeared recently claiming that this substance, given directly, produced progestational proliferation of the endometrium resembling that brought about by progesterone. Mr. Philip C. Pratt, of Johns Hopkins Medical School, repeated and extended these experiments in our laboratory with completely negative results. The very attractive hypothesis directly relating vitamin C to progesterone action must therefore be considered untenable.

#### ABSORPTION OF PELLETS OF CRYSTALLINE HORMONES

Dr. T. R. Forbes, of Johns Hopkins Medical School, has published further results of his studies of absorption of pellets of crystalline hormones. This work was explained and a summary of previous results given in Year Book No. 40. In one of his new papers (see bibliography) he gives a table of the time required for 90 per cent absorption of subcutaneous pellets of 20 crystalline compounds, including cholesterol, 17 other steroids, and 2 stilbestrol derivatives. When made up into uniformly compressed pellets, 6 to 10 mg.

in weight, and implanted beneath the skin of rats, these various substances required from 29 days to more than a year for 90 per cent absorption of the pellet. Cholesterol was not absorbed at all. The table will be useful to other workers. In another contribution Dr. Forbes shows that pellets made from large crystals are absorbed as well as those made from small crystals of the same compound. Three different steroid hormones were used in this experiment. In a third contribution it is shown that the age of the rats receiving hormone pellets strongly influenced the rate of absorption. When testosterone monopropionate was used, the rate of absorption fell with age, during the first two months, as shown by the following figures: 33 per cent of pellets implanted at 16 days was absorbed after 12 days' implantation; 31 per cent if implanted on the 30th day; 26 per cent if implanted about the 50th day; if at the end of 1 year, 26 per cent.

#### EXPERIMENTAL FIBROIDS

It is a well known fact that continuous treatment with estrogenic hormones tends to produce fibrosis of the female reproductive tissues, differing in type and degree according to the species of animal. In guinea pigs, as shown by Nelson and by the extensive work of Lipschütz and his students during the past six years, the estrogen-produced fibrosis takes the form of extensive fibroid tumors. One of the former students of Professor Lipschütz, Dr. Luis Vargas F., spent more than a year at our laboratory as a Guggenheim Fellow, working on special aspects of the problem. In the first place, an attempt was made to produce fibroid tumors in rhesus monkeys, using the same experimental technique which had been used with the guinea pig. None of the 4 animals treated with estrogen by subcutaneous implantation of tablets of estradiol developed

fibroid tumors or disseminated miliary fibrous nodules such as are seen in the guinea pig. Two, however, showed pronounced fibrosis of the myometrium, and one of these had marked operative adhesions and fibrosis at the site of an exploratory laparotomy; another had a keloid plaque of fibrosis on the stomach. The rhesus monkey therefore seems to be less sensitive to estrogen-induced fibroid changes than is the guinea pig.

Dr. Vargas also made experiments to find out whether the pituitary gland has a necessary part in the production of fibroid tumors in the guinea pig. He found that removal of the anterior lobe of the pituitary gland (hypophysis) caused no change in the intensity, extent, or distribution of the tumor process. As an incidental finding, it was noticed that the mammary glands of the hypophysectomized guinea pigs grew only when the operation had been incomplete, leaving a fragment of the anterior lobe. Failure of the mammary gland to grow after hypophysectomy is therefore a good test of the completeness of the operation.

#### ATTEMPTS TO CAUSE OVULATION IN THE MONKEY

It is now well known that the pituitary gland contains a hormone or hormones having the property of stimulating growth and function of the ovary, and also that substances of similar function exist in the urine of pregnant women and the blood of pregnant mares. Complete function of the ovary, including the discharge of egg cells, obviously depends upon successful operation of the pituitary hormones. It has, however, been difficult to produce ovulation in adult experimental animals by use of the available hormone preparations. Except in experiments with the rabbit, only a few successes have been reported. Dr.

C. G. Hartman, while a member of our staff, interested himself in the problem as it concerns the rhesus monkey. It is not only a matter of theoretical interest, for nonovulating monkeys have not been uncommon in the Carnegie colony, and it is of practical value to render them fertile if possible. Dr. Hartman published in 1938 the none-too-encouraging results of 104 experiments. He now presents 46 more experiments on 37 nonovulating females. Among these there were 6 cases in which hormone treatment appears to have caused ovulation. This favorable result was obtained, in various cases, with pituitary follicle-stimulating hormone and with a preparation from pregnant mare serum. Hartman's papers contain a very clear and instructive account of the gonad-stimulating hormones now commercially available. He cites many interesting details as to their action in monkeys, including the matter of overstimulation of the ovary (a

frequent result), injury to follicles, recovery after treatment, refractory states, etc.

#### COLLECTING UTERINE FLUID

Dr. Somers H. Sturgis, who worked in the laboratory as a Rockefeller Fellow for several months until called to service with the Medical Corps of the U. S. Army, was able to complete the first stage of a unique effort to study the fluid of the uterine cavity in primates and the physiology of its secretion. By skillful experimental procedures he made uteroabdominal fistulas in 4 monkeys, through which he collected the uterine fluids, measuring the rate of accumulation. He found that adrenalin and intravenous normal salt solution increased the rate of flow, and that pilocarpine did not increase it. There was some evidence that factors which influence the rate of flow locally or cause systematic changes of blood volume may produce changes in the rate of uterine secretion.

### CYTOLOGY

#### NUCLEOLAR VACUOLES

Dr. Warren H. Lewis reports observations on nucleolar vacuoles, made in this laboratory and in the Wistar Institute of Philadelphia. Vacuoles in the nucleoli of cells have often been noted by cytologists, but their origin and significance is unknown. Dr. Lewis therefore attempted to discover correlations between their occurrence and some cultural or cytological characteristics of normal and of malignant fibroblasts in tissue culture. Studying hun-

dreds of cultures including a wide range of tumors, no consistent relations were found between the number of cells having nucleolar vacuoles and the culture medium, the extent of migration, the life of the culture, the number of mitoses, the amount of pinocytosis, or any cytological feature of the nucleoplasm such as the number of nucleoli, the number of fat globules, the mitochondria, the neutral-red-staining vacuoles and granules, or the size of the central area. The article is illustrated by striking photographs.

### COMPARATIVE ANATOMY OF PRIMATES

Among the contributions of the group of comparative anatomists in the Department of Anatomy of the Johns Hopkins Medical School, closely associated with the Carnegie Department of Embryology, there are several dealing with topics in the comparative anatomy of primates.

#### RUDIMENTARY DIGITS

Dr. W. L. Straus, Jr. points out that a few of the Primates normally have one or more stunted or rudimentary digits. This statement applies to the second finger and second toe of the lorises (lemurs); to the thumb of spider monkeys (Atelinae),

guereza (*Colobus*), chimpanzee, and gorilla, the thumb and first toe of orangutan, and the fifth toe of man.

There appears to be no absolute correlation between bones and muscles. In some rudimentary digits the skeleton is the more severely affected (fifth toe of man, hallux of orang), in others the musculature (thumbs of great apes and of certain Colobinae), and in still others both of these structures show essentially similar degrees of curtailment (second fingers and toes of Lorisidae, thumbs of *Ateles* and *Colobus*). The long, extrinsic muscles of the affected digit distinctly tend to be more defective than the short, intrinsic muscles.

The significance of some normally rudimentary digits (fifth toe of man, hallux of orang) is entirely obscure. The arrested digits of the Lorisidae, however, seem to be related to the peculiar pincers-like grasp of their hands and feet, in which the first and fourth are the dominant digits. As for a rudimentary or stunted thumb, this apparently can be correlated with the habit of "brachiation." This mode of locomotion, nevertheless, is not necessarily accompanied by a poorly developed thumb, as witness the Hylobatidae (gibbons). These animals clearly are adapted to a brachiating life in a manner quite different from that of Atelinae, Colobinae, and great apes.

The evidence produced by a comparative study of the thumb supports not only the view that man's phylogeny did not include a pronounced brachiating stage, but also that view which denies man other than very remote relationship to the great anthropoid apes.

#### CROWN PAD AND CHEEK PAD

Most of the specialized superficial structures seen in the Primates are of epidermal or glandular nature, for example the sternal glands of the orangutan or the ischial callosities of catarrhine monkeys. Two, however, represent modification of

the connective tissue, namely the crown pad of the gorilla and the cheek pad of the orangutan. The first of these has apparently never been carefully studied from the histological standpoint. Dr. Straus has recently been able to dissect the head of a female lowland gorilla, which had a crown pad although the latter has been considered a peculiarity of the mountain species. The pad proved to consist largely of heavy bundles of collagenous connective tissue like that of the corium of the skin, with which it blended. The cheek pad of an orangutan was quite different, consisting largely of subcutaneous fat.

#### BALANCE OF THE HEAD

In man the occipital condyles, by which the head is jointed to the spine, are much more nearly under the center of gravity of the head than in any other mammal. This human peculiarity is undoubtedly connected with man's erect posture and facilitates the balancing of the head on the spinal column. Dr. A. H. Schultz now asks the question: How closely does the head of modern man approach the conditions for perfect equilibrium, and to what degree does man differ in this respect from other primates? He uses a simple apparatus in which the head is posed on the occipital condyles as a fulcrum. The anterior part of the head is then slightly heavier. Weights are suspended from the inion (a standard point at the occipital protuberance) sufficient to balance the head. Again, the upward pull necessary to balance the head when applied at the most oral point is measured by weights and a pulley. The percentages of these two weights in relation to the total head weight are then compared. In man they are more nearly alike than in other mammals; that is, the head is more nearly balanced at the occipital condyles. Study of ape and human heads at various ages shows that the conditions for balancing the head are



more alike in man and the apes at early than at late stages of growth. In man the head becomes more nearly balanced with advance in age.

The weights thus found empirically should be in inverse ratio to the length of the lever arms, from the fulcrum to

the joints at which the weights act. Since they do in fact correspond very closely to expectation, Dr. Schultz has been able to use measurements instead of actual weights in studying casts of fossil human skulls. These (Gibraltar and Rhodesia man) have the ratio characteristic of modern man.

## NERVOUS SYSTEM

### DEVELOPMENT AND REGRESSION OF REFLEXES, POSTURES, AND PROGRESSION

Dr. Marion Hines, of the Department of Anatomy of Johns Hopkins Medical School, has completed a notable study of the development of motor responses and activities in the young rhesus monkey. This work, which might be classified as the embryology of behavior, will interest not only neurologists but all who are concerned with infant behavior in the human species and with the earliest phases of infant care and education. The observations cover the last month of gestation and the first year of life. Thirty-one animals were used, including 5 fetuses removed by Caesarean section. These 5 and 15 others were bred in the Carnegie colony by Dr. Carl G. Hartman.

Within the space of 3 months the infant macaque develops from a state of complete dependence on its mother to one of relative independence. At the end of a year he uses his body like an adult. During all this period of rapid development Dr. Hines has kept her little subjects under constant observation in quiet surroundings, with the cooperation of a trained technician. Her success in this arduous task is made evident to the nonspecialist reader by the series of photographs accompanying the article. Charming beyond the wont of scientific monographs, they were made by Dr. Hines herself to illustrate the technical points discussed in the text.

In view of the detailed character of the

work, only a general summary can be given here. Observation of the changing muscular behavior of prenatal and infant monkeys supports the idea that the development and regression of the various reflexes and postures are an expression of the progressive maturation of one part after another of the central nervous system, and in particular the cerebral cortex.

All newborn animals show a period of tonic innervation of the flexors and associated muscles. During this period the grasp reflex is dominant, and reaching and grasping movements are used in progression, in righting, and in the early exploration of objects.

A spastic state follows, in which the "clasp knife" type of resistance to passive movement and brisk irradiating tendon reflexes are present, and in some animals the positive supporting reaction is markedly exaggerated.

As the spastic state regresses, coinervations of somatic musculature appear and disappear. Fixation of proximal muscles is observed, and the discreteness of use of distal muscles becomes more evident.

The order of development of response to sensory stimuli proceeds from relatively simple reflex patterns to more complex responses, which increase in their discreteness until it becomes evident that the young monkey is able to localize certain moieties of general cutaneous sensibility and to respond to sounds heard and to objects seen as if they held definite significance.

Dr. Hines remarks that anyone who has watched the development of the human infant from the neurological point of view will be astonished at the similarity of the order of the development in the two primates.

A very striking fact which has come out of the studies of Dr. Hines during the past ten years is that some of the characteristic reflexes and spastic reactions which the infant develops, and then loses again as its behavior becomes more and more coordinated, reappear in adults if certain areas of the cerebral cortex are removed. This affords an argument in reverse to support the general theory of the development of motor activity and response which grows out of this and similar studies on other species.

#### DEVELOPMENT OF THE MOTOR END PLATE

Dr. Fidel Cuajunco, of the University of the Philippines, who was a guest worker in the Johns Hopkins Department of Anatomy several years ago, prepared in the Department of Embryology a series of nerve endings in muscles of embryos. He continued his study of these in Manila, and in 1940 he published in volume

XXVIII of our Contributions an account of the embryology of the human neuromuscular spindle. A second paper, on the development of the motor end plate, was on hand for publication at the time of Pearl Harbor and was prepared for press with the kind assistance of Dr. Marion Hines, necessarily without consultation with the author. His conclusions are highly detailed. Summarizing them briefly, it appears that the terminal loops of nerve fibrils come into contact with the sarcolemma of muscle fibers about the 11th week, when the transverse striations are just beginning. By the 13th week the network of nerve terminals of the end plate is beginning to form, and the adult pattern is recognizable in the 14th week. Active growth and reorganization take place from the 14th to the 24th week, leading to the formation of the large multiple end plates.

Spontaneous movements of fetal limbs occur before the union of muscle and nerve is established. Reflex contractions begin after the nerve endings have connected with the muscle fibers, and after the 16th week both muscle fibers and motor end plates are in a high enough state of development to permit strong muscular movements.

### APPARATUS AND TECHNICAL METHODS

#### VERTICAL CAMERA

About five years ago Dr. C. H. Heuser and Mr. O. O. Heard collaborated in the design of a vertical stereocamera for use particularly in photographing embryos. Mr. Heard constructed three of these instruments in the Department's shop. Practically all the photomicrography of the laboratory, both monocular and stereoscopic, is done with them. The excellent service they have given has prompted publication of an illustrated description. One of the unique features of this camera

is an arrangement for posing very small specimens under a binocular microscope, which is swung out of axis and replaced by the camera. The camera may be set in advance for any given magnification, since the distance between the lens board and the plateholder end of the camera can be fixed before focusing. The object is placed on an adjustable stand which is moved vertically to bring it into focus. The design and construction of the instrument afford a very high degree of rapidity and precision.

## DIFFUSION AND POPULARIZATION OF RESULTS

This department recognizes its responsibility for making the results of its investigations available in easily interpretable form for use by the world of science, for general application, and for understanding by the people. This duty has frequently been pointed out by the leaders of the Carnegie Institution, most notably perhaps in a passage in the President's Report of 1937 (Year Book No. 36) relative to the views of Elihu Root on the subject. During the past year a number of opportunities have presented themselves for service to the scientific and to the general public. We have received, for example, numerous requests for lantern slides illustrating the Hertig-Rock series of early human embryos, to be used in teaching embryology in medical schools and colleges. In order to fulfill these requests without interrupting the research work of our photographic laboratory, with the permission of Dr. Hertig and Dr. Rock we have placed duplicate negatives with the General Bio-

logical Supply House of Chicago. Lantern slides, better than a teacher can make by copying our illustrations, can thus be obtained at reasonable cost and of course without profit to the Carnegie Institution.

Several embryologists writing or revising textbooks have requested and received prints for use as illustrations. Still more noteworthy, a new high-school textbook of home care and nursing, by Dr. Alma Long of Purdue University, contains a handsome series of photographs of human embryos and fetuses, especially selected by us from our files. The Vanuxem Lectures for 1942 on "The hormones in human reproduction," given at Princeton University by the Director of the Department, appeared in book form during the year. The volume, which is written for the educated general public, refers extensively to the work of the Department of Embryology and contains among its illustrations several from our collections.

## PERSONAL

At the end of June 1943, Miss Rebecca D. Hepburn retired from active service. Miss Hepburn was secretary to Professor Franklin P. Mall, founder of the Department, prior to its organization. Her term of

service therefore covered the entire history of the laboratory, and the contribution she has made by her efficiency and devotion is appreciated by all who have worked here.

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## DEPARTMENT OF GENETICS

*Cold Spring Harbor, Long Island, New York*

M. DEMEREC, *Director*

In war research there has not yet been any great demand for personnel with the training possessed by members of this Department, nor for facilities such as are offered by our laboratories. Consequently, our participation in work related to war problems is not as extensive as we should like it to be. An effort has been made, however, to take up problems brought about by the war, and this effort has been successful in a number of instances.

MacDowell, Potter, Fano, and Demerec are actively engaged in a cooperative project with the Biological Laboratory of the Long Island Biological Association, under contract with the Chemical Warfare Service; and the mouse colony of the Department is being extensively used in this work.

In cooperation with the Department of Agriculture, Warmke has continued and extended his breeding studies with Russian dandelion and with hemp, initiated soon after the outbreak of the war. By sampling roots of the Russian dandelion at different levels, he has found a gradient in latex percentage. The latex percentage at the extremities of roots may be three or four times as great as that at the crown. This is of basic importance in the selection and breeding programs being carried on by the various cooperating laboratories. Tetraploid plants of the Russian dandelion have been grown to maturity and have been submitted to the Department of Agriculture for comparative rubber determinations. The polyploids appear to have certain important advantages, including increased general vigor, broader leaves, and larger roots. They retain the normal sexual behavior of the diploids. The studies on hemp now indicate that marihuana con-

tent can be reduced by breeding. After only one generation of selection, offspring from selected low-content parents have been shown to have a significantly lower marihuana potency than those from selected high-content parents. New tetraploid hemp strains from quality fiber stocks have been produced and will be submitted for comparative fiber tests. Additional tests carried out with improved techniques confirm the increased marihuana content of triploids and tetraploids, reported tentatively last year.

One of the many hazards that have been accentuated by war conditions is that of injury to the human eye resulting from exposure to ultraviolet radiation. With the purpose of learning the causes of such injury and determining the minimum dosage capable of producing detectable changes in the tissues of the eye, a cooperative study has been undertaken by Kaufmann and Dr. A. Hollaender, of the National Institute of Health, Bethesda, Maryland. It is known that the cells of the basal layer of the corneal epithelium undergo divisions, which provide the material necessary for the continual replacement of the cells of the upper layer. Studies conducted at this Department indicate that exposure to ultraviolet radiation of wave length 2537 Å at an intensity of about 3000 ergs per square centimeter per second for periods of only 5 to 10 minutes will arrest cell division for a considerable length of time. In order that more exact information might be obtained concerning the effect of wave length 2537 Å on cell division, Dr. J. Gordon Carlson, of the University of Alabama, was asked by the National Institute of Health to investigate this

problem by using tissue cultures of neuroblast cells of the grasshopper. Working at this Department, he has found that exposure for only 7.5 seconds at an intensity of 110 ergs per square centimeter per second produces a measurable retardation in cell divisions. This result indicates that dividing cells are extremely sensitive to wave length 2537 Å, which fact was taken into consideration when the tolerance dose for that wave length was established.

Since new work brought about by the war has occupied only a fraction of our time, the members of the Department have proceeded with their regular research. A brief summary will be given here of the individual reports of the various members for the year ending September 1, 1943; the reports in full are printed on the succeeding pages.

Working with maize, McClintock has continued investigations on the breakage and fusion of chromosomes. The new evidence obtained by her suggests that the capacity for fusion of a recently broken end of a chromosome will be lost if this chromosome undergoes a division cycle before fusion with another such end has occurred. In another investigation, undertaken to determine the amount of crossing over that may occur within small segments of a chromosome, the results indicated that a relatively large amount of crossing over may occur between the loci of two mutants that are physically close to each other on the chromosome. This is in agreement with results obtained in studies on *Drosophila*, where it was found that in several chromosomal regions frequency of crossing over does not correspond to the physical distance between loci. McClintock's studies with broken chromosomes have been greatly facilitated by the development of a method for increasing the number of such chromosomes that could be recovered. This method utilized differential pollen-

tube growth, which favored those grains carrying newly broken chromosomes. The gametic recovery of newly broken chromosomes 9 rose from the previously available 3.6 per cent to as high as 90 per cent. These breakages frequently delete a terminal segment of the short arm of chromosome 9. When the deletion is small, the deficient chromosome is male- and female-transmissible. Plants homozygous for these deficiencies show mutant characters ascribable to the deficiency. These same mutants are repeatedly and independently produced whenever the short arm of chromosome 9 is subjected to breakage, regardless of the method which brings about this breakage. Two types of deficiency mutant, pale-yellow seedlings and white seedlings, have been isolated. Together with the normal chromosome producing green seedlings, they form an allelic series of descending order of dominance, which is related to a progressive increase in the length of the deficiency. Thirteen of these deficiency mutants are now receiving intensive study.

In addition to work on the extensive cooperative project with the Department of Agriculture already mentioned, Warmke has made a preliminary study, on *Nicotiana*, of the relation of the arrangement of the microspores within the tetrad to the number of germ pores in the mature pollen grains. Results obtained so far indicate that the latter is not directly controlled by the former, as has been commonly supposed.

In cooperation with Hollaender, Demerec and Sansome have continued irradiation experiments with the fungus *Neurospora*. It has been found that the frequency of X-ray-induced mutations increases approximately in proportion to the dosage, even when very high dosages are applied. Treatment with 126,000 roentgens induced about 78 per cent mutations, which is the highest induced-mutation rate

on record. In experiments with ultraviolet radiation, the mutation-rate curve reaches a certain peak and then, unlike the X-ray curve, begins to drop. This drop has been observed by Hollaender in several fungi. In *Neurospora* it is probably caused by heterogeneity of spores. It has been observed that 2650 Å, which is absorbed by nucleic acid to a high degree, is the wavelength most effective in producing mutations, that 2280 Å is least effective, and that 2937 Å is intermediate between the two.

Kaufmann has continued with attempts to influence the fusion of *Drosophila* chromosomes broken by X rays, through subsequent treatment with ultraviolet and infrared radiation, and high and low temperatures.

Fano has completed experiments in which sperm of *Drosophila* was treated with neutrons. His findings indicate that about 40 per cent of sex-linked lethals carried chromosomal aberrations. Through a study of the data on complex rearrangements induced by X rays, Fano has reached the conclusion that the healing of potential breaks is influenced by mechanical stress that may be exerted through movements of the chromosomes. Several theoretical questions arising from irradiation problems have been considered by him. With Mr. L. D. Marinelli, he devised a plan for experiments to study the time-intensity factor; he has also contributed a new calculation to the hypothesis that large ion clusters are responsible for X-ray-induced chromosomal breakage, and supplied a qualitative explanation of the disagreement between calculations and observations of the physical action of ionizing radiations.

MacDowell reports that the incidence of spontaneous leukemia in certain groups of hybrid mice is profoundly influenced by the age of the mother from the non-leukemic strain. The highest incidence is given by the young from the youngest

mothers. As the mother's age increases, the incidence falls off to virtually zero. As the proportion of leukemics declines, the leukemics live to a greater age. The leukemics from the youngest mothers die, on the average, much earlier than the non-leukemics; the leukemics from the oldest mothers die as much after the non-leukemics, whose life span is not influenced by the age of their mothers. Genetic differences in leukemic tendency that are shown clearly when mothers are young are hidden when mothers are old. MacDowell and Bryson have obtained direct embryological evidence of retardation in the growth of the ribs of screw-tail mice and resulting distortion of the sternal bands. This supports the conclusion that the unique pattern of the unsegmented sternum, characteristic of this mutation, is not a direct expression of the gene, but rather the result of the failure of the rib-ends to approach the mid-line at the normal rate.

The age at which female doves and pigeons become sexually mature, as shown by the laying of their first egg, was earlier found to be greatly influenced by both environmental (seasonal) and genetic factors. Riddle and Hollander now report that, incidental to the selection to establish "endocrine" races 22 years ago, a segregation of genetic factors was obtained in one race of doves which at all seasons delays the attainment of sexual maturity by one to two months. The genetic influence on age at maturity now separates this slow-maturing race of doves from another dove race to a greater extent than the latter is separated from typical breeds of pigeons. A few years ago it was learned that female sex hormones, estrogens, greatly increase the calcium of the blood in pigeons and fowl. The parathyroid glands were known to exercise much influence on the serum calcium, and it seemed probable that estrogens produce their effect by stimulat-



ing the parathyroids. Riddle, Rauch, and Smith have shown that estrogens are fully effective in increasing the "bound" or non-diffusible fraction of the serum calcium in pigeons whose parathyroids have been completely removed. For this aspect of blood-calcium regulation in birds the parathyroids are therefore not necessary, but their indispensability is indicated by the fact that in their absence tetany may occur even though the "bound" calcium exists at higher than normal levels in the blood.

In previous years Steggerda has made anthropometric studies on adults of the Maya Indian, Dutch white, Jamaica Negro, and American Negro groups. This year he

is presenting a similar study on adult Navajo Indians, based on measurements of 150 males and 100 females. It appears that the Navajos are of medium body build, and rather light in weight; that their trunks and arms are relatively long; and that they are brachycephalic. During a 10-year period Steggerda has collected data about the growth of corn on the same plot of ground in Yucatan. He found that the yield decreased because of weed competition, grass encroachment, and insect pests. Steggerda has completed three papers for the *Handbook of South American Indians*, which is to be published by the Smithsonian Institution.

## MOUSE GENETICS

E. C. MACDOWELL, J. S. POTTER, V. BRYSON, M. J. TAYLOR, E. N. WARD, AND T. LAANES

The facilities and personnel of this group have been placed at the disposal of a special project under the Chemical Warfare Service. Dr. Potter has given full time to this work for the entire year, and Dr. Bryson joined him in the summer of 1943. The mice required for this work are being supplied, and responsibility is being taken for care, clinical observation, gross autopsy, and histological study of the experimental animals. The strains of mice especially concerned with leukemia are being maintained, as are important lines of transplanted leukemia; but the active work on leukemia has been virtually limited to the maintenance of established long-time experiments.

### FOSTER-NURSING EXPERIMENT

The question has been raised (Year Book No. 41, p. 199) whether the effect of the strain of the foster nurse on body weight at weaning, as observed in the special foster-nursing experiment, might have any connection with the nurse's influence, previously observed, upon the incidence of

spontaneous leukemia. Up to the present very few cases of leukemia have appeared in this experiment, but the size differences due to the strain of the nurse reported last year have been entirely outgrown. At the age of 12 weeks—8 weeks after weaning—one of the four categories of mice still showed the effect of nurse's strain on body weight, and two of these categories showed an effect of nurse's strain on tail length. By 9 months all traces of the nurse's effect on body weight and tail length had disappeared.

The long persistence of the effect of the nurse's strain on size is the surprising feature of this result; and yet even more interesting is the immediate and transitory nature of the differential influence of foster nurses from two strains, as compared with the increasing and permanent differential influence of mothers from these same two strains. The mice in the foster-nursing experiment are all first-generation hybrids; half were borne by mothers from one strain, half by mothers from the other. Mice from mothers of different strains, but

nursed by females from the same strain, showed only a suggestion of size difference at 4 weeks; at 12 weeks and at 9 months size differences according to mother's strain were marked. Males showed this consistently in both tail length and body weight, whereas females showed it in tail length but only very questionably in body weight. This finding is apparently due to a sex difference in the factors regulating adiposity, which in females masks the effect of the mother's strain on weight.

It is possible that the influence of a female as a mother and as a nurse is dependent on the same mechanism, but if so why should the effect from mothers increase with age and the effect from nurses disappear? The increasing divergence with age of mice from mothers of different strains more closely parallels the expression of sex differences and suggests that the maternal influence is intrinsic or germinal. The final outcome of the foster-nursing experiment in terms of the incidence of leukemia may differ from the originally anticipated conclusion if the interpretation of the nursing effect offered in the following section should be substantiated.

#### MOTHER'S AGE AND SPONTANEOUS LEUKEMIA

An important addition has been made to the list of extrinsic variables that appear to modify the incidence of spontaneous leukemia in hybrid mice (Year Book No. 40, p. 243) with the discovery that mother's age has an outstanding influence. The mothers in this case were from the inbred, so-called non-leukemic strain in the second backcross experiment that has been repeatedly mentioned in these reports. The exact age of the mother at the birth of every litter could readily be determined from the records; but this had never been done, for the importance of mother's age was unsuspected. The second backcross experiment was designed to test for genetic segregation

among 50 males of the first backcross of the leukemic and non-leukemic strains C58 and StoLi. These males were bred, and the young (50 or more) sired by each of them were called a family. Since the mothers were all inbred StoLi, the genetic differences between families were due to the fathers alone. When the mice of each family were divided into two groups, according as their mothers were older or younger than 18 weeks at their birth, the incidence of leukemia per family of mice with younger mothers showed a frequency distribution markedly higher than that for mice from the older mothers. Indeed, the divergence of these two distributions was more impressive than that of corresponding distributions of the families divided on any other basis that showed correlation with the incidence of leukemia. This was true even for the difference due to the two strains of nurses, which led to the special experiment on foster nursing. It is now evident that the next experiment on the incidence of spontaneous leukemia will have to be a direct confirmation of the effect of mother's age.

A more complete analysis of the data shows a progressive reduction in the proportion of leukemics as mother's age increases. With the variation due to nurses from different strains eliminated by considering only mice nursed by StoLi females (mostly their own mothers), and with the effects of the genetic differences between fathers reduced by dividing the families into four groups according to the total percentage of leukemia per family, the percentage of leukemia within each group of families was plotted according to mother's age. The group of "high leukemia" families gave 35 per cent leukemia for youngest mothers (8 to 15 weeks old), less than 2 per cent for oldest mothers (32 weeks or more), and for intermediate ages points along a curve connecting these

extremes. The next two groups of families also gave their highest incidence of leukemia (25 per cent and 15 per cent) with the youngest mothers. The percentages fell off as mother's age advanced, as in the "high" families; but they fell less rapidly, for the same end point was indicated. The "low leukemia" group, starting with 5 per cent for youngest mothers, showed only a slight decline as mother's age increased. Thus the effect of mother's age depends on the family (paternal) tendency. If the leukemic tendency is strong, the influence of mother's age will be marked; if weak, any influence of mother's age will be hard to demonstrate. If only young mothers had been used, the differences between families would have been more striking; if only old mothers had been used, family differences would have been entirely concealed.

Another measure of the effect of increasing mother's age is the associated lengthening of life of the leukemics. The life span of non-leukemics shows no change with mother's age. The leukemics with youngest mothers, when nursed by StoLi females, died on the average 120 days before the non-leukemics. As the mother's age increased, the averages rose regularly until they were 120 days above the non-leukemics. The reduction in the proportion of leukemics is accompanied by a delay in the death of the leukemics.

These results indicate that age brings some change in the mothers from the "non-leukemic" strain, whereby they transmit something to their young that tends to ward off the manifestation of leukemia. The nature of the change in mothers, and the manner of passing on this something, are matters of broad importance. The action appears to be specific for leukemia and not an increase in general resistance to causes of death, since the life span of non-leukemics is not influenced. Nor is the change in mothers due to some antigenic

action of hybrid young on the mother that in turn modifies later litters, since the same influence of mother's age appears when only the first hybrid litter from each mother is counted. The influence is transmissible before the birth of the young, since the young nursed by Bagg albino females, when classified as above, show clearly the reduction in leukemia with the advancing age of own mothers. But the influence is also transmissible after birth, through nursing, for when such transmission is prevented by fostering with the Bagg nurses, the decline in the proportion of leukemics with mother's age is notably less rapid. With the old mothers of 32 weeks, the group of "high leukemia" families nursed by Bagg foster mothers gave 15 per cent leukemia and the other groups of families were distinguishable instead of being all close to zero. The mice nursed by Bagg females show the effect of mother's age on length of life of leukemics; but here again the effect is less marked, being only from 70 days before the non-leukemics for youngest mothers to 50 days after non-leukemics for old mothers. Again, the average age of non-leukemics remains constant. The difference depending on the strain of the nurse may be explainable by the presence or absence of that part of the mother's age influence that is transmitted through nursing.

#### THE SCREW-TAIL STERNUM

As the first of a series of embryological studies on different organs of the screw-tail mouse, Bryson has made extended observations on the development of the unique, unsegmented sternum. In connection with this study a series of 12- to 18-day embryos have been sectioned, all of the same genetic constitution except for the variations in occurrence of the screw-tail gene. This series naturally provides material for the study of other parts as well as the sternum. In the report of last year,

an interpretation of the striking features of the screw-tail sternum was proposed, which placed the responsibility for these features on the ribs rather than on a direct modification by the gene of the intrinsic properties of the anlage of the sternum. That the ribs, which seem normal in adults, should be responsible for the dramatic deviations of the sternum is surprising; but Bryson's observations provide convincing embryological evidence that this is the case. In addition to studying the sections directly, he made reconstructions and models as well as many dissections of embryos especially prepared to reveal skeletogenous tissues. He found the earliest certain deviation of the screw-tail sternum at 14 days after conception, when the longitudinal bands that subsequently unite at the mid-line to form the sternum are wider than normal. Later the widening becomes more marked, and lateral projections at the rib connections indicate tension at these points, whereas normally the sternal bands are indented by the stress of the ribs elongating toward the mid-line. Though the bands are still separate for most of their length (at 14½ days), the distance between the ends of opposite ribs is greater in screw-tails than in normals. Bryson measured the distance between the ends of second ribs and of seventh ribs in 29 screw-tail and 78 normal embryos 14½ days old. When the embryos were classified by weight, the average distance decreased as embryo weight increased; that is to say, the rib ends were approaching. But within each weight class this average was greater for the screw-tails than for the normals.

In the heavier classes, individual variability was reduced and the differences between screw and normal became statistically significant. Since the greater distance between the ends of pairs of ribs in screw-tails appeared before the two halves of the sternum were brought together, it is evident that the ribs themselves are responsible for the position of their ends, and that the wide sternum of screws is a result and not a cause of the position of the rib ends.

In order to compare screw and normal ribs, rib volumes were calculated from the weight of cut-out projections of sectioned ribs. The rib volume of screw-tails was less than that of normal embryos of the same weight. It seems necessary to assume some depression of rib growth in screw-tails which effectively retards instead of facilitating the movement of the sternal bands toward each other. In spite of this, cellular readjustments accomplish the union of the inner margins of the bands; but this is accomplished at the sacrifice both of thickness and of length. At the same stage that the sternal bands are beginning to widen, as they stretch toward each other away from the retarded ribs, they also begin to be shortened. Measurements of the distance between first and seventh ribs on the same side of 14½-day embryos show that, within the same weight group, first and seventh ribs are closer together in screw-tails than in normals, and that as the weight of the embryos increases, the difference between averages for screws and normals increases progressively from very slight and statistically insignificant to markedly significant.

## ENDOCRINE STUDIES

O. RIDDLE, W. F. HOLLANDER, R. A. MILLER, F. E. VISSCHER, E. L. LAHR, G. C. SMITH, AND V. M. RAUCH

The products of hormonal regulation are observable in higher animals at all life stages, from immature egg to the end

of adult life. At all developmental stages, cross sections of the gradually expanding cone of organization disclose patterns of

structure and function which hormones have helped to form. In some cases it is clear that a change in the controlling genes is associated with a modified expression of a hormone's effect or action. In all cases the hormones contribute to the regulation of development, or to bodily maintenance, or to both. Most of our effort this year has been directed toward an extension of our knowledge of hormonal regulation in those areas in which our earlier studies had pointed to significant facts and relationships.

#### HORMONE ACTION IN CARBOHYDRATE AND FAT METABOLISM

During recent years this laboratory and a few others have engaged in an attempt to learn which hormones of the pituitary gland are responsible for bodily changes such as increased sugar in the blood (glycemia), anti-insulin effects (glycotrophic response), increase of acetone bodies in the blood (ketosis), increase of liver and muscle glycogen, and increased deposit of fat in the liver. The anterior lobe of the pituitary gland, whose hormones often act upon and through other "target" glands, is currently regarded as the chief or only source of these several effects; a useful test of this view can now be reported. During a part of the past two years Riddle, Visscher, and Marvin have investigated the possible share of substances arising in the posterior lobe of the pituitary gland in the production of the effects named above. This particular study will be considered first, and somewhat more fully than related items, because no similar study has been reported for birds and because the results indicate that posterior-lobe products, though responsible for hitherto undescribed glycotrophic-like effects, are not the regulators of the above-mentioned phases of carbohydrate and fat metabolism.

*Effects of substances originating in the posterior pituitary.* A single preparation, in the form of a standard powder, was made from carefully dissected posterior lobes of cattle which had been quickly frozen at an abattoir. These glands were defatted and dehydrated with acetone (to 125 g.), ground, extracted for 3 hours in alkaline (pH 9.5) ethanol (60 per cent), then centrifuged, and a part of the extract precipitated at pH 5.0. The supernatant fluid obtained from this procedure provided the substance (preparation No. 779; 11.2 g.) which was first very extensively assayed for its content of the several pituitary hormones, and was used thereafter in direct determination of effects on blood sugar, liver and muscle glycogen, and liver fat of normal pigeons of uniform race and age. These last-named determinations were made on nearly 200 treated birds; and 65 test birds and 38 untreated control birds were used in comparable studies on the action of a commercial preparation from posterior lobes (puititrin).

Measurements were made of the effects of single and of daily injections of the two types of posterior-lobe preparation. Groups of birds were killed and sampled after 2 to 5 daily injections and at 2, 5, 10, 17, and 24 hours after a single injection. At 24 hours before sampling, every bird was force-fed 15 g. of mixed grain and thereafter was allowed no food.

The alkaline extract had little or no effect on the blood acetone of pigeons and rats. The principles contained in anterior pituitary extracts that increase liver fat and blood ketones in pigeons are not produced in the posterior lobe; it is also shown that those responses are not produced by intermedin and are probably not produced by the "specific metabolic principle" of Collip.

The level of blood sugar was slightly, but significantly, raised at 10, 17, and 24

hours after a single injection of the alkaline extract. At these same periods 2 to 4 units of pituitrin increased the blood sugar insignificantly.

The level of muscle glycogen was not maintained in normal pigeons injected with alkaline extract No. 779 and fasted 24 hours; pituitrin had little or no effect.

The alkaline extract of posterior pituitary tissue maintained liver glycogen at higher than fasting levels at 10, 17, and 24 hours after a single injection, and at 24 hours after 2, 3, 4, and 5 daily injections. The data of Riddle and Opdyke show that this prolonged effect on liver glycogen is not obtained in equal degree by purified anterior pituitary hormones nor by whole extract of anterior pituitaries, though it is obtained by high doses of insulin. These results involve a sparing of liver glycogen (glycotrophic-like action) but not a new formation of glycogen, since, after 48-hour fasts, the values obtained from uninjected birds were the same as from birds injected 17 or 24 hours earlier.

The glycotrophic-like and glycemic actions of this alkaline extract are probably of pharmacological rather than physiological significance. These responses are apparently associated with digestive disturbance and they may result from repeated overstimulation of the pancreas; they should not be regarded as specific actions of any hormone.

*The posterior pituitary and heat production.* Some observations on effects of a posterior pituitary extract (described above) on heat production and digestion were made by Mrs. Smith. Respiratory metabolism measurements were made on a group of 8 birds injected with No. 779 at a time when the digestion and absorption of their last meal should have been in progress. At 7 hours after the birds were fed their usual 15 g. of grain, and at 7 hours after their last (third) injection of

the alkaline extract, their heat production was  $-1$ . The respiratory quotients of 3 of these birds taken under these conditions averaged 0.73 (range, 0.71 to 0.76); this value seems definitely lower than that of uninjected controls (average for 12 tests,  $0.81 \pm 0.014$ ; range, 0.74 to 0.89), and suggests a diminished oxidation of sugar in the injected birds. Data obtained by palpation of the crops of birds injected with No. 779, or with pituitrin, indicated that the crops of such birds were emptied rather more rapidly than those of control birds. It is not known whether digestion was more or less complete in the crops that were more speedily emptied. None of the crops in either group was completely empty at 7 hours after feeding; it therefore seems probable that, despite apparent ingress of sugar into the blood from their alimentary tracts, the tissues of injected birds were oxidizing little if any more sugar than at the end of a 24-hour fast.

*Cortical hormones and glycogen storage in pigeons.* In studies on rats, Long and Kendall and their associates have shown that 11-dehydrocorticosterone is especially effective in increasing the stores of liver glycogen. With hormone supplied by Dr. Kendall, a sufficient number of tests have been made on pigeons by Riddle and Vischer to show the absence of a comparable effect in this species. Doses of 3 mg. failed to increase the liver glycogen of 17 fasting (24 hours) young Carneau pigeons at 5, 17, and 24 hours after injection. In 5 birds treated with implanted pellets (10 to 12 mg.) during 4 days there was also no effect. Pancreatectomized rats are especially sensitive; but in 3 pancreatectomized pigeons no effect was observed at 24 hours after injection of 3 mg. of this hormone. The muscle glycogen stores were measured concurrently on all birds, but in no group of birds was an increase of muscle glycogen found.

Since anterior pituitary hormones, including corticotrophin, were earlier shown to have some ability to increase the glycogen stores of pigeons, it was desirable to learn whether desoxycorticosterone acetate is capable of producing this effect. A small number of tests made on normal and hypophysectomized pigeons at 5 hours after a single injection, and at 24 hours after the last of 6 daily injections, have failed to indicate any action on the glycogen stores. Under a stimulus supplied by the anterior pituitary, the adrenal probably produces a hormone which increases the glycogen

livers of the two age groups respond about equally at 5 hours after injection; but between 5 and 17 hours after the insulin injection the livers of adult birds increase their store of fat little or not at all, though livers of young birds double their fat stores during this period. The additional (unpublished) data of Riddle and Opdyke on fat stores of young pigeons (at 10, 24, 48 hours, etc.) make it clear that in such birds maximum storage is reached at about 12, 17, or 24 hours, and that thereafter the fat stores diminish despite repeated daily injections.

EFFECT OF AGE ON THE ABILITY OF INSULIN TO INCREASE THE STORAGE OF FAT IN THE LIVER

AGE OF PIGEON	PERCENTAGE OF LIVER FAT AFTER INJECTION OF CONTROL PROTEIN (MUSCLE EXTRACT) AND INSULIN		
	Muscle extract (5 hours)	Insulin, 30 units (5 hours)	Insulin, 30 units (17 hours)
Young.....	(6) $3.86 \pm 0.24$	(5) $7.35 \pm 0.54$	(8) $14.75 \pm 1.07$
Adult.....	(6) $4.52 \pm 0.30$	(7) $8.06 \pm 1.29$	(7) $7.57 \pm 1.17$

stores of birds; that hormone, however, has not yet been identified. At the moment, these results serve to emphasize the fact that species differences are of such magnitude that a variety of animals must be utilized in endocrine research.

*An age factor in the action of insulin on liver fat in pigeons.* In a study on the action of insulin on the liver glycogen stores, Goldblatt noted that these are much less variable in fasted young than in adult rabbits. It was earlier observed by Riddle and Opdyke (Year Book No. 40) that a first dose of insulin, and a first dose only, greatly increases the deposit of fat in the liver of young pigeons. Some comparisons have now been made by Rauch and Riddle of the action of insulin on the liver fat of young and of adult pigeons. The results are shown in the accompanying table.

An unusual type of difference associated with aging is evident. It appears that the

## HORMONES AND GROWTH

The studies described below were carried out as items of a more comprehensive inquiry, partly reported previously, on the role of hormones in the maintenance of body weight after removal of the pituitary or the adrenals. These studies are based on the view that adequate knowledge of the mechanism through which the pituitary gland affects bodily growth must include a determination, in young animals of various species, of all generally favorable effects of pituitary activity. These effects surely include such things as changes in amount of food consumption, hormonal support of body weight after removal of pituitary or adrenals, and similar support or increase of weight of essential "vegetative" organs by both pituitary and "target" hormones.

*Hormonal support of weight of pancreas.* Studies reported earlier showed that during

the 10 days following the removal of the anterior pituitary gland of pigeons there is a marked loss in body weight (20 per cent) and a notably greater loss in the weight of the intestine (43 per cent) and pancreas (54 per cent). These weight losses, except that in the pancreatic tissue, could be prevented and even overcompensated by moderate daily dosage with highly purified prolactin alone. Maintenance of the weight of the pancreas seemed, according to those earlier studies, to require thyrotrophin in addition to prolactin. During the present year Miller and Riddle have obtained evidence that hormones of the adrenal cortex and thyroxin (when the latter is administered together with prolactin and adrenal cortical hormone) actively assist in maintaining the weight of the pancreas after the pituitary is removed.

The anterior pituitary gland was removed from successive groups of 5 to 8 White Carneau pigeons at 1.5 months after hatching (weight about 450 g.). The food and water intake of all control and treated groups was measured. Suboptimal daily doses of prolactin (1 unit) and of desoxycorticosterone acetate (1 mg.) were each found to provide partial support to the pancreas, and when these quantities of the two hormones were given together their effects on the pancreas were additive. It was next learned that the administration of minute doses of thyroxin (5 gamma daily) in connection with prolactin and cortical hormone provided still further support to the pancreas. This action of thyroxin is the more notable since, when given alone, it did not significantly affect the weight of the pancreas, and since its effective support of pancreatic tissue was not accompanied by any increase in food consumption. Under dosage with these minute amounts of the three hormones the loss in weight by the pancreas, during 10 days following hypophysectomy, was reduced from 54 per

cent to 10 per cent although food consumption remained 32 per cent below normal. Since anterior pituitary hormones stimulate the production of thyroxin and adrenal hormones, it thus appears that at least three anterior pituitary hormones (prolactin, adrenotrophin, thyrotrophin) share in the maintenance of pancreatic tissue.

*Action of prolactin and cortical hormones on body weight and food intake of adrenalectomized pigeons.* Our earlier demonstration of the action of hormones of the adrenal cortex in maintaining weight of the body and some essential organs in pituitaryless birds made it necessary to learn whether the similar action of prolactin on body weight and food intake was exercised through or upon the adrenal glands. Although it was known that most of the preparations of prolactin used in those particular studies were almost free of any ability to enlarge the adrenals of 2-day chicks and 21-day rats (and thus apparently free of adrenotrophin), only tests of the effectiveness of prolactin in completely adrenalectomized pigeons could resolve this question. Results of a study by Miller and Riddle, as summarized below, show that these actions of prolactin are not mediated by the adrenals.

It was found that adrenalectomized young Carneau pigeons fed 1.75 g. of a salt mixture daily showed an average period of survival of 9 days. Such pigeons take little food and lose weight. Either adrenal cortical extract or desoxycorticosterone acetate maintained life in adrenalectomized pigeons. Daily doses of 2 mg. of desoxycorticosterone acetate fully restored the rate of increase of body weight and the daily food consumption to levels characteristic of normal unoperated pigeons. Highly purified prolactin induced more than normal gains in body weight when adrenal insufficiency was not acute, and it restored food intake to a level almost equal to that of unoper-



ated birds. A group of adrenalectomized birds given high dosage of both prolactin and adrenal cortical extract showed more rapid gains in body weight and larger food intake than has ever been observed in normal unoperated pigeons of the age used in these tests.

*Effect of adrenal removal on heat production.* Two years ago Riddle and Smith made a preliminary report on the effect of adrenalectomy on the respiratory metabolism of adult pigeons. Repeated tests on 12 operated adults seemed to show that their basal metabolism had been affected only slightly; a decrease of about 6 per cent was observed and the respiratory quotient seemed unchanged. Careful autopsies of the longest-lived survivors of that group of birds, together with later experience, cast doubt on the completeness of the operation in some of the birds used in that test, and thus aroused doubt concerning the conclusions. In this laboratory Miller later found that adrenalectomy can be performed completely and satisfactorily on young pigeons, and these birds maintained (on a salt mixture) free from terminal symptoms long enough to permit the desired measurements. The two adrenals were removed in two operations separated by an interval of one week. During the present year metabolism measurements (at 30° C.) on non-fasting birds and on those fasted 24 hours have been made on a satisfactory number of completely adrenalectomized young Carneau pigeons at 7 to 10 weeks after hatching.

It was found that respiratory quotients of young pigeons are modified little if at all by the loss of the adrenals 3 to 7 days earlier. A few measurements of rectal temperatures indicate that little or no change of temperature results from loss of the adrenals, and probably there is no significant difference between the body temperatures of operated birds measured at 5 to 12 and at 24 hours after food.

Non-basal (5 to 12 hours after taking food) values for heat production were obtained from 13 birds both before and after the removal of one adrenal. The average values from the two groups of tests differed by only 1.0 per cent. Basal values (after 24-hour fast) on 6 of these same birds differed by only 0.9 per cent. It is evident therefore that the removal of a single adrenal does not measurably affect the metabolism. Non-basal values (5 to 12 hours after food) were obtained on 37 birds after one adrenal was removed and again at 3 to 7 days after removal of the other adrenal; the second measurements showed an average reduction of 10.2 per cent, and a reduction was observed in all the six groups of birds subjected to the test. The respiratory quotients of the two series were 0.84 and 0.81, respectively. Values which are known to be basal (24 hours after food) in the case of intact pigeons were obtained from 26 birds after one adrenal was removed, and again at 3 to 7 days after removing the other adrenal; the latter measurements indicated an average increase in heat production of 6.4 per cent, and an increase was observed in all the five groups of birds subjected to the test. Respiratory quotients from the two series averaged 0.70 and 0.73, respectively. Additional measurements were obtained either after removing both adrenals (15 tests, non-basal; 24 "basal"), or after removal of one only (44 tests, non-basal; 18 basal), but not at both of these stages. These data from unmatched individuals confirm the results stated above.

Heat production in pigeons was thus shown to change but little during the first few days following removal of the adrenals. The direction of the change, however, was found to differ in an unexpected way according to whether the last food was consumed at 5 to 12 hours, or at 24 hours, before measurement; the supposedly "basal" values (24 hours after food) obtained by

us are about 6 per cent higher, and the values at 5 to 12 hours after food are 5 to 10 per cent lower, than those for intact animals. This confusing result at first appears to support the paradox of a basal heat production (4.708 Cal./kg./hr.) definitely higher than the non-basal value (4.244 Cal./kg./hr.). Other evidence indicated that this anomalous result rests on a delay of the specific dynamic action of food in the absence of the adrenals; such a delay has been observed by Brownell and Hartman in adrenalectomized dogs.

#### PARATHYROIDS AND ESTROGENS IN THE REGULATION OF THE SERUM CALCIUM

Largely because of the peculiar suitability of pigeons for such studies, this laboratory was earlier able to show that the serum calcium of female birds is more than doubled during the short, recurrent periods when a pair of ova become fully mature in the ovary. It was also shown that estrogens, but not androgens, will cause similar or greater increases of the serum calcium in old or young birds of either sex and in pigeons deprived of such organs as the pituitary, testis, pancreas, and thyroid. Though others have shown that the parathyroid gland normally assists in the regulation of the serum calcium, very little is known of the mechanism by which either parathyroids or estrogens exert this action. Whatever this mechanism may be, it probably is more or less concerned in bone growth and in the formation of calcium phosphate stones in the urinary tract. During the past year four distinct advances have been made in a still unfinished study of this problem; and cooperative studies on two different phases of the problem have been undertaken with two research groups in New York City.

Though complete removal of the parathyroids was necessary in order to learn what estrogens can do in their absence, the location and distribution of the parathy-

roids in pigeons was unknown. Because of other special advantages of the pigeon, it was necessary to overcome this difficulty. Dissections and histological study by Rauch and Smith showed that, at least in the race of pigeons (Carneau) most used in this study, the two pairs of parathyroids typically lie outside and posterior to the thyroids. A fortunate result of this circumstance is that our studies on parathyroid-ectomized birds, unlike those on most mammals, are not complicated by simultaneous removal of part or all of the thyroids.

The second advance resulted from the development by Smith of a technique for complete removal of the relatively inaccessible parathyroids. This involves removal of the glands on the two sides of the thorax in operations separated by a few days. Some hours preceding the second operation, and usually for several days thereafter, the birds were given dihydrotachysterol (AT<sub>10</sub>) in order to prevent the early crisis that would otherwise result from the rapid decline of the serum calcium. The feeding of calcium gluconate also was found especially effective in preventing the symptoms of hypoparathyroidism.

A third and much desired test has been made on 25 of these animals by Riddle and Rauch. In pigeons completely deprived of their parathyroids, estrogens were found to increase the serum calcium as effectively as in intact animals. Heavy dosage with estrone or estradiol benzoate during 4 or 5 days sometimes raised the calcium level by as much as 500 per cent. In all the 10 cases in which a second (or third) period of estrogen dosage was given, the serum calcium rose for a second or third time above a pre-injection level that was definitely subnormal. The parathyroids are therefore not essential to this action. It was found, however, that following the termination of a series of estrogen injections, and while the calcium level is still at

or above normal, some of these birds may show tetany or even die in convulsions. It is evident, therefore, that the injected estrogen does not fully replace the normal action of the parathyroids, but affects solely or mainly the nondiffusible (or "bound") calcium.

Some attention is being given to the effects of both parathyroidectomy and estrogen dosage on bone resorption and bone deposition. The skulls of these operated and treated animals, including some which were both parathyroidectomized and hypophysectomized by Smith, are being utilized in a special study by Dr. E. P. Fowler, under the auspices of the Central Bureau of Research of the American Otological Society.

Finally, estrogen treatments of unoperated birds of both sexes, and also those phases of the reproductive cycle of females which involve highest and lowest points in apparent parathyroid activity, are being utilized by Rauch and Riddle in an effort to provide a functional interpretation of the histology of the parathyroid glands. Although this study is unfinished, it now seems that the so-called "light cells" undergo increase in number and in size, acquire a more granular cytoplasm, and have smaller fat droplets at a time when parathyroid activity, estrogens, and serum calcium are all at higher levels.

During the latter part of the present year our laboratory has cooperated with Dr. Ephraim Shorr, Department of Medicine, Cornell Medical College, in a study of the calcium, phosphate, and citrate changes in the bones of pigeons at ovulation and during ovarian inactivity.

#### ENDOCRINE RACES AND RECORDS

During the past twenty-two years a large amount of breeding data, and a larger amount of data on weights and measurements of organs of endocrine significance

from selected inbred strains, have been obtained for many races of doves and pigeons. These records are now being analyzed and summarized with the special aid of Dr. Hollander. During the past sixteen years the basal metabolism of members of all these races and their hybrids has been intensively investigated, and the summarization of these records has engaged most of Mrs. Smith's time during much of the present year. It is hoped that all results of this prolonged study of heat production, as affected by race, sex, hybridity, season, etc., may be reported next year.

Current breeding tests supervised by Hollander involve outcrosses of the hermaphrodite-producing stock, as briefly described last year, and further genetic tests with "scraggly" and ataxia. The latter characters are being recombined with features of the White Carneau. This should provide a useful check on the mode of inheritance of ataxia, and will perhaps perpetuate these interesting mutations in a more vigorous stock. The breeding studies incident to a clarification of the relation of goiter to embryonic vigor are mentioned in another part of this report.

In the analysis of the data for organ weights from individuals of many generations of the various races or strains of both doves and pigeons, it is found that in most races there exists a sex difference in body weight, liver weight, intestinal length, spleen weight, and thyroid weight. Rather generally the several organs listed are heavier in the female, although body weight is greater in the male. Much less adequate evidence for this conclusion was cited several years ago (Year Books Nos. 27, 28).

A summary, now almost complete, of data on the relation of race and season of origin to the age at which an individual female dove or pigeon becomes sexually

mature deserves special mention. On the basis of the much less abundant data available 12 years ago (Year Book No. 30) it was noted that, although genetic racial differences are evident, birds hatched in the period from September to January usually become sexually mature (lay their first egg) at an earlier age than do birds

modify or determine the median age at which the first egg is produced. This genetic difference is particularly evident for the two races of ring doves, which differ more from each other than the early-maturing dove race differs from pigeons—another species. In the doves this genetic difference is especially significant since it

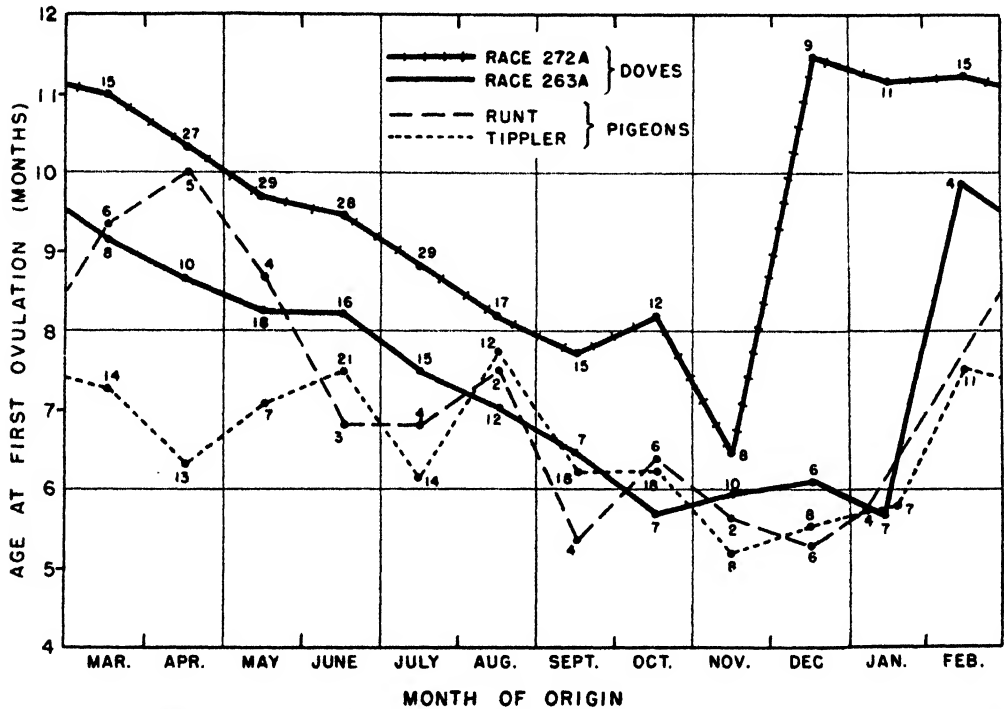


FIG. 1. Parallel fluctuation of age at first ovulation in females of a late-maturing race of ring doves (272A), of an early-maturing race (263A), and of two representative breeds of pigeons. Both month of birth and genes (race) affect the age at which sexual maturity is attained. The points on the curves are median values for the number of birds indicated by the numerals.

hatched in the period from February to June. The data obtained to date for two of our selected ("endocrine") races of doves, and for a large and a small race of pigeons, have been graphed by Hollander in the form shown in figure 1.

The graph shows that age at sexual maturity, in all the four races, is markedly affected by an environmental factor, namely, something associated with season. It is also made clear that genetic factors

is an example of a character which was unintentionally segregated and established by the selection involved in the formation of these two "endocrine" races.

#### RELATION OF GOITER IN PIGEONS TO EMBRYONIC VIGOR

Last year's report briefly noted an apparent relation between weakness in pigeon embryos and endemic goiter in their parents. Investigations led by Hollander have

yielded significant results. A survey of a large amount of data indicates that in adult pigeons the weight of thyroids which may properly be called "normal" seldom exceeds 0.02 per cent of the body weight. Since thyroids exceeding 0.02 per cent of body weight have been fairly frequent in our colony of pigeons, and since their histology had suggested a deficiency of iodine, a test of the curative effect of adding potassium iodide to the diet was conducted over a period of 6 months. During this period 31 pairs of breeding birds received a supplement of KI in their mineral or grit mixture; the amount consumed weekly was not more than 0.5 mg. of KI per bird, and the average supplementary

thyroids of the 5 female parents were examined and found to be goitrous (3 to 5 times normal). Unilateral thyroidectomy was performed on 3 of them and the glands examined histologically (all hypertrophic, no colloid). Thereafter these females were given doses of 10 mg. of KI, and in most instances the dose was repeated about once each month. Records for production of weak young before and after treatment were strikingly different. Previous to treatment, all the young from these selected pairs were weak at hatching; following treatment, none of the 23 young obtained was weak at hatching.

The condition in the newly hatched young which is here called "weakness"

EFFECT OF ADDING POTASSIUM IODIDE TO THE FOOD OF PIGEONS ON THE VIGOR OF THEIR OFFSPRING AT HATCHING

GROUP	NO. OF PAIRS	TOTAL EGGS	HATCHED	YOUNG AT HATCHING	
				Vigorous	Weak
Iodized.....	31	200	138 (69%)	132 (96%)	6 (4%)
Control.....	24	161	103 (64%)	53 (51%)	50 (49%)

intake was probably about 0.2 mg. Twenty-four breeding pairs, caged in the same building, served as control; they received the regular diet with no KI supplement. In each group the usual genetic types of pigeons in the colony were represented. The favorable effect of the KI supplement on the young is indicated in the accompanying table.

Sample thyroids taken from newly hatched young of these two groups showed that eggs from iodized parents produced young with thyroids ranging from 2 to 5 mg. Those from the control group were much more often enlarged, ranging from about 3 to 30 mg.

Five pairs of parents with exceptional records for the production of weakling young were selected for special study. The

consisted not only of evident debility but of anemia and defective closure of the umbilicus. These several symptoms may or may not appear together. In general, the affected young are perfectly formed and not stunted.

Histological studies were made by Lahr on thyroids of three groups or types of day-old young. These groups included normal young from normal parents, normal young from KI-treated goitrous parents, and weak young from goitrous parents. The glands of the normal young contained small, round follicles with medium-high epithelia and with small amounts of stainable colloid in some follicles. Those from KI-treated goitrous parents had thyroids similar to those of the normal young but showing greater amounts of a denser col-

loid. The weak young from goitrous parents had thyroids with a higher epithelium, with some hyperemia of the gland, and with no colloid. With a single exception, the large thyroids found in Carneau pigeons aged 2 to 3 months were simple goiters (hyperactive glands). In them the epithelia were high and there was either no colloid or mere traces of a watery colloid. When KI was fed directly to birds of this age and thyroid type, the epithelia became very low (resting) and considerable amounts of densely staining colloid were present.

In untreated adult birds approximately two-thirds of the large thyroids found were similar to those of pigeons aged 2 to 3 months. The other third of adult birds had goiters of colloid type, with huge follicles filled with a diffuse colloid and with very atrophic epithelia. A few marginal follicles scattered among the atrophic ones might appear normal or even hypertrophied. Regardless of their earlier condition, all birds that had been treated, even several months before, with desiccated thyroid tissue or KI were found uniformly to have resting epithelia and fair quantities of dense colloid.

The above breeding data and the associated histological study show that, in the absence of supplementary iodine, goiter has developed frequently; this in turn indicates that the iodine content of the basic diet (and water supply) was too low for some pigeons of our colony. Simple goiter in the parent birds results in simple goiter in their embryos at hatching, and here it

is associated with weakness. Correction of the goiter in the parents by iodine therapy prevents both goiter and weakness in the young.

#### STEROID HORMONES AND MATERNAL BEHAVIOR IN DOVES

Following the termination of earlier studies on the induction of maternal behavior in fowl and rats by various hormones, Lahr and Riddle have conducted a series of tests on the action of certain steroid hormones, when administered as subcutaneously implanted pellets, in ring doves. The pellets were removed after a period of 8 to 12 days. In these studies, not entirely completed, both immature and adult birds of both sexes were subjected to brief tests. It has been found that complete incubation, with subsequent feeding of young, can be induced promptly in previously unmated adult birds of either sex by progesterone or by desoxycorticosterone acetate. Only about half of the adolescent males, and none of three immature females hitherto tested, responded to progesterone. Some evidence indicates that testosterone propionate induces broodiness in both adolescent and adult females. Unimplanted controls, otherwise similarly tested, do not become broody within the time limits set for these tests. That the effective steroids tend to induce a release of prolactin from the bird's own pituitary is indicated by a concurrent enlargement of the dove's crop sacs and usually by secretion of crop milk after the normal interval.

#### THE GENE

M. DEMEREC, B. P. KAUFMANN, U. FANO, EVA R. SANSOME, AND HELEN GAY

##### RADIATION EXPERIMENTS

*Effects of ultraviolet radiation on mitosis.*  
Injury to the human eye resulting from exposure to ultraviolet radiation consti-

tutes an industrial hazard of major importance in the present war emergency. Adequate protection against ultraviolet can be assured, but through negligence or ac-

cident it is not always obtained; and therefore it becomes important to determine the minimum dosage which can produce detectable changes in the tissues of the eye. Dr. Kaufmann and Miss Gay have been cooperating with Dr. A. Hollaender, of the National Institute of Health, Bethesda, Maryland, in a study of the effects of ultraviolet radiation on the mitotic cells of the corneal epithelium. In the preliminary work, eyes of various mammals were used, including the mouse, rat, cat, rabbit, and monkey. Of these the rabbit cornea proved most adaptable for the type of analysis undertaken. The corneal epithelium of this animal consists of four to five layers of cells resting on the underlying connective tissue. Under normal conditions mitoses can be found in the basal layer. To facilitate identification of the various stages of mitosis, a technique was devised for stripping the epithelium as a unit from the entire cornea, staining in acetic orcein (which colors the nuclei without clouding the surrounding cytoplasm), flattening, and mounting in euparal. Nuclei of the basal layer can be recognized clearly despite the overlying cells, and the mitotic stages can be identified with great accuracy, except possibly the earliest prophase and very late telophases.

Survey of a series of eyes from normal or untreated rabbits revealed considerable variability in the number of mitoses per unit of area. Striking differences were found not only between different animals, but also between the two eyes of one animal, and even within the area of a single cornea. For example, inspection of the flattened epithelium of an entire cornea gave the following numbers of mitoses per square millimeter in a series of four arbitrarily determined concentric rings, proceeding outward from the center: (1) 31.7, (2) 30.7, (3) 23.4, (4) 9.25. Much greater

variability is found to exist when smaller areas are compared.

Experiments with ultraviolet have been restricted to radiation of wave length 2537 Å. One eye of the animal was treated; the other served as a control. Destructive and damaging effects of ultraviolet irradiation on the corneal epithelium had been obtained in several earlier experiments, but the effect on the dividing cells was less well known. Our work has shown that an exposure of 5 to 10 minutes, at an intensity of about 3000 ergs per square centimeter per second, blocks all mitotic activity, so that 7 to 8 hours after irradiation no metaphases or anaphases are detectable. Although the smallest dose necessary to produce such a blocking effect can readily be determined, it is less easy to measure the minimum dose that can upset or alter the rate of mitotic activity. One of the chief handicaps to this analysis is the considerable variability in frequency of mitosis in the corneal epithelium, as a result of which control or standard values are not readily obtained. For these reasons, it seemed desirable to collect data of the type desired from more suitable material; and Dr. J. Gordon Carlson, of the University of Alabama, was requested by the National Institute of Health to lend his services and the tissue-culture method that he had perfected in a more direct attack on the problem.

Dr. Carlson spent the summer months at the Department of Genetics on a preliminary study of the effects of ultraviolet radiation of wave length 2537 Å on the neuroblast cells of the grasshopper, *Chortophaga viridifasciata*. These cells can be grown in artificial culture medium, where they can be kept under continuous observation with the microscope; they are sufficiently large so that all stages of mitosis can be recognized and studied; and they are situated on the surface of the embryo,

so that the ultraviolet rays enter them without loss through absorption by overlying tissues. During treatment the left half of each embryo was shielded to serve as the control. Counts were made of the numbers of neuroblasts passing through metaphase and anaphase in both the control and the irradiated side of the embryo during the 6-hour period beginning with treatment, and the effects were expressed as the ratio of the treated to the control numbers. At an intensity of 110 ergs per square centimeter per second this ratio is 0.97, 0.76, 0.61, and 0.58 for exposures of 7.5, 15, 60, and 240 seconds, respectively. Experiments on the effects of fractionated treatment and of treatments at different intensities are still incomplete; but present results suggest that within certain limits these factors are less important than the total dosage.

The mitotic effect of ultraviolet radiation is similar to that of X radiation, in that the number of metaphases and anaphases decreases rapidly after treatment because of a blocking of cells in prophase. It differs strikingly from the X-ray effect, however, in the absence of a compensatory period after recovery, the number of metaphases and anaphases never rising significantly above the normal. This result is probably due to distribution of the effect over a considerable portion of the prophase and possibly even interphase stages, and the resulting failure of abnormally large numbers of cells to accumulate in a limited blocked stage.

Changes are also produced in the nucleoli. These are a pair of nuclear bodies that develop during the reconstitution of the nucleus at telophase. Normally they form at a distal constriction on one of the larger pair of chromosomes. Since they arise as the matrix of the chromosome disappears, they are often looked upon as accumulations of a material from the

matrix. Evidence from ultraviolet treatment supports this concept in two respects. First, the well formed chromosomes of late prophase, if irradiated just before breakdown of the nuclear membrane, are gradually supplanted by groups of small granules resembling nucleoli. These subsequently disappear as the chromatin threads re-form. Second, the fully developed chromosomes, if treated after the breakdown of the nuclear membrane, develop many small nucleolus-like bodies at telophase instead of the two larger nucleoli typical of the untreated cell. These changes suggest that the ultraviolet affects the nucleoli indirectly through the matrix of the chromosome. If the cell is in interphase or prophase, however, at the time of treatment, the two nucleoli are gradually transformed from their normal irregular, diffuse, granular form into highly refractile, regular spherules. This change, which is reversible, reaches a maximum of development less than an hour after a 2-minute treatment.

*Radiation experiments with Neurospora.* Studies on the effects of ultraviolet and X radiation in inducing mutations in *Neurospora crassa* have been continued by Mrs. Sansome, Dr. Demerec, and Miss Zimmer, in collaboration with Dr. Hollaender. This fungus has the disadvantage that, because of its rapid spreading growth, the number of spores that can be isolated in each experiment is limited. It has the great advantage, however, of being amenable to genetical analysis; the variants produced may be tested genetically, and the results obtained may be used as a check on other fungi which do not have a sexual stage and therefore cannot themselves be subjected to genetical test.

In the ultraviolet work, experiments were continued with the wave length 2650 Å, which had been shown to be that most effective in producing mutations. Two



repeat experiments confirmed the low effectiveness of wave length 2280. Two experiments with 2937 gave results intermediate between those for 2280 and those for 2650. In six out of eight experiments, the percentage of mutants reached a peak at a certain energy level and dropped with increase of energy. The peak occurred at approximately the same energy level in each experiment, but the height of the peak varied from experiment to experiment. The decline in the mutation rate is associated with low survival rate. One particular Fl+ line consistently gave low mutation rates and failed to give the characteristic curve. It is thought that the shape of the mutation curve and the fact that spore samples differ in their actual mutation rate may be caused by the spores' being heterogeneous in their response to ultraviolet radiation. It is possible that spores differ in their capacity to absorb ultraviolet radiation, or that the nuclear response differs at different stages. A number of the ultraviolet-induced mutants are being tested to determine the frequency of mutants having more than one induced change. Preliminary investigations indicate that 15 out of 39 cases tested may be such mutants. This extremely high coincidence of mutations tends to confirm the supposition that the spores are heterogeneous in their response to ultraviolet radiation.

Further X-radiation experiments using a wave length of 0.3 Å were made. There was a possibility that mutant spores might differ from normal in their times of germination or in their survival value, in such a way that the proportions of mutants to normals might vary according to whether early- or late-germinating spores were taken. Accordingly, spores isolated on the first day of germination were kept separate from those isolated on the second and third days, and the mutation rates of the

two groups were compared. There was no significant difference between the percentages of mutants in early- and in late-germinating spores. This has considerable practical importance, since it means that the mutation rate may be established from samples of spores taken at any convenient time; it is not necessary to isolate all the spores that germinate on a particular set of plates.

The results obtained from different dosages at low intensity (about 240 roentgens per minute) are given below. The difference in dosage was effected by varying the time of exposure.

Dosage (r)	Total survivors	Per cent mutants
Control .....	810	0.6
2,250 .....	723	2.8
4,500 .....	421	5.0
9,000 .....	677	6.2
13,500 .....	592	7.4
18,000 .....	640	10.6
22,500 .....	204	16.7
31,500 .....	325	24.6

The rise in mutation rate with increased dosage approximates a linear increase. There is no drop in the rate above a certain dosage point, as in the case of ultraviolet-irradiated spores. The survival ratio is difficult to determine in *Neurospora* because of the rapid growth of the early-germinating spores. Moreover, X-radiation treatment somewhat accelerates the germination of the spores, so that the survival ratio cannot be determined by sampling the control and irradiated spores at definite times; all the spores that germinate on a particular plate must be recorded. Nevertheless it has been established that, even at 31,500 r, about half the spores survive the treatment as compared with the number of control survivors. Since it was desired to increase the dosage until an appreciable amount of killing was obtained, still higher dosages were given. For these it

was necessary to use higher intensity than can conveniently be delivered by our instrument; and we are indebted to Mr. L. D. Marinelli and Dr. R. S. Anderson, of the Biophysics Department of the Memorial Hospital, New York, for giving the high-intensity treatments.

The results of the high-intensity (5400 r per minute) irradiations are as follows:

Dosage (r)	Total survivors	Per cent mutants
Control	527	0.2
15,750	657	14.3
22,500	274	24.8
31,500	772	31.5
63,000	32	53.3
126,000	51	78.5

It can be seen that the mutation rate continues to increase with increased dosage. Moreover, the mutation rate in the high-intensity experiments is approximately linear, although it is appreciably higher than in the low-intensity experiments. At 63,000 r the survival rate is about 2.5 per cent and at 126,000 r about 0.01 per cent of that of the control. At these dosages the mutation rate continues to increase. Therefore, there is no drop in the mutation rate associated with a low survival rate, such as was observed in the ultraviolet experiments.

The results indicate that an increased mutation rate may be associated with high intensity. It is hoped to test whether this is indeed the case or whether the difference in results obtained from the treatments given at Cold Spring Harbor and at Memorial Hospital is due to some other cause.

The Lindegrens' observation that crosses between X-ray-induced mutants and a normal standard line tend to be more sterile than control crosses was confirmed last year. Further investigation has shown that such sterility is found in crosses involving phenotypically normal cultures from treated spores as well as those involv-

ing visible mutants, but that the percentage of sterile types is much higher in the mutants. Since sterility is to a large extent caused by chromosomal aberrations, our observations indicate a correlation between visible mutants and chromosome aberrations. The percentage of sterile types is greater at high than at low intensity, and increases with dosage. The correlation between visible mutants and sterility appears to rise with increases in dosage and intensity; but further data are needed to test this point. The correlation between visible mutants and chromosomal aberrations is in agreement with the apparent intensity effect, since it has been shown in *Tradescantia* that high intensity increases the number of aberrations.

It is planned to make further experiments on the correlation between sterility and visible mutants, and in particular to obtain, if possible, the mutation rate for mutants not associated with sterility. It seems probable that the apparently simple linear X-ray dosage curve is, in reality, composed of two curves: one of mutants associated with chromosomal aberrations, the other of mutants independent of such aberrations.

*Neutron experiments.* The results of the neutron experiment on *Drosophila* by Dr. Fano mentioned in Year Book No. 41 can now be discussed, since cytological analysis of the salivary-gland preparations has been completed by Dr. Sutton. Out of 62 X chromosomes that carried sex-linked lethals induced by neutron treatment, 25 (i.e., 40 per cent) had a rearrangement in the same chromosomal region in which the lethal was located. None of the lethals had a readily detectable deficiency. The frequency of association of lethals and rearrangements appears to be much higher in neutron-treated than in any other material, when the various special circumstances of this and other experiments are considered.

This finding is not unexpected, since there is evidence to indicate that neutrons, as a rule, produce fewer gene mutations and more (or at least not fewer) chromosomal rearrangements than energetically similar doses of X rays.

The demonstration that the proportion of lethals associated with rearrangements can be as high as 40 per cent when the total frequency of lethals is 6 per cent increases the difficulty of interpreting an already difficult situation. There are two types of sex-linked lethal, both of which are detected by the CLB method; namely, gene mutations and chromosomal rearrangements. It is generally assumed that the first of these is induced at a rate proportional to the radiation dosage, and the second at a rate approximately proportional to the square of the dosage. How, then, can the sum of the two components be actually proportional to the radiation dosage, especially when the quantitative contribution of the second component is not negligible? No satisfactory hypothesis has yet been found to explain this discrepancy.

#### RADIATION THEORY

*The time-intensity factor.* In many radiobiological (genetic and nongenetic) reactions, the effect of a given dosage of radiation depends on the "time-intensity factor"; that is, it is a direct function of the intensity ("intensity effect"), and is lower when the treatment is intermittent than when it is continuous, provided the intensity remains the same ("fractionation effect"). This phenomenon has been the object of considerable attention, inasmuch as it might furnish important clues to the process of recovery of the biological material from the action of radiation. The intensity effects have been determined by comparing the results of continuous irradiations with constant dose and different

intensities. Extensive experimental and theoretical investigations along this line have not yet supplied crucial information on the course of recovery. While developing a mathematical formulation of the effect of the time-intensity factor on X-ray-induced chromosomal aberrations in *Tradescantia*, Mr. L. D. Marinelli, of Memorial Hospital, concluded that fractionation experiments, consisting of two high-intensity irradiations separated by a variable intermission, ought to be better suited than continuous irradiations to investigation of the time factor. Dr. Fano joined the investigations at this point. Further consideration indicated that Marinelli's suggestion has general significance. The course of recovery may be followed most easily in fractionation experiments, because radiation can be delivered in a short time during which recovery is negligible, and recovery takes place during the intermission without having its effect masked or interfered with by continuing irradiation. A method was developed showing how the results of fractionation experiments should be combined to calculate an index of recovery, and how special tests can be designed to determine the complexity of the recovery process. Considerations of this type have led to a more comprehensive point of view with reference to various radiobiological theories previously proposed.

*Genetic action of X rays by means of large ion clusters.* It is widely believed that the absence of any wave-length effect in the genetic action of X rays proves that this action is produced by single ionizations or by *small* ion clusters, such as commonly occur along the paths of photo- or Compton electrons in tissue. This belief, however, relies on the assumption that *large* clusters of ionizations are mainly due to the condensation of many small clusters occurring by chance at very short distances

from one another. This assumption is incorrect, because a large cluster is more likely to occur as a single unit, owing to exceptionally close approach of the path to one particular atomic electron. This argument has been used recently by Lea and Catcheside in an attempt to explain the quantitative data on the effects of various radiations on *Tradescantia* chromosomes. They calculated that clusters of approximately 20 ionizations ought to be most effective in breaking chromosomes. Their work, however, did not include a quantitative evaluation of the frequency of occurrence of large ion clusters. An approximate evaluation has been provided by Dr. Fano through an application of existing theories of the impact of fast electrons against atoms and molecules. He calculated that 1 r of X rays produces approximately 0.1*n* clusters (of *n* or more ionizations) per cubic micron. This calculation lends additional support to the theory proposed by Lea and Catcheside.

*Ionization yield of radiation energy.* The dosimetry of most radiobiological experiments rests on the fact that the number of ions produced by radiation in an air chamber may be taken as an indirect measure of the number of ions produced and of the total amount of energy spent by radiation per unit volume in tissue. This method depends largely upon the following experimental result: Calling *V* the amount of radiation energy absorbed by a certain volume of a substance, and *P* the number of ionizations produced within it, the ratio  $\epsilon = V/P$  (that is, the average energy spent per ion pair produced) is generally of the order of magnitude of 30 electron-volts, whatever the ionizing radiation used and the substance absorbing it. In particular, the values of  $\epsilon$  found for different substances show no general correlation with the energy *I* actually required to ionize one individual molecule of the

substance. For instance,  $\epsilon$  is slightly lower for He than for H<sub>2</sub>, even though *I* is 50 per cent greater for He than for H<sub>2</sub>. Previous calculations of the physical action of ionizing radiations do not account for this fact, but on the contrary predict that  $\epsilon$  should be approximately proportional to *I*.

Dr. Fano has given a qualitative explanation of this disagreement. The average energy  $\epsilon$  is always greater than *I*, because a part of the radiation energy is spent for other purposes than ionization. Most of the energy thus "wasted" goes into excitation of optical levels. In order to explain how *I* may be especially large for a particular substance without bringing about a correspondingly large value of  $\epsilon$ , one must show that the "waste" of energy  $\epsilon - I$  is especially small in that substance. This end seems to be achieved through the following findings: (a) Accurate information available for the three characteristic atoms H, He, and Li shows that their aptitude for undergoing optical excitation, rather than ionization, and hence the probable "waste" of energy when radiation acts upon them, is approximately in inverse ratio to the value of *I*. (b) Qualitative discussion of quantum mechanical properties of atoms and molecules indicates that this correlation between the aptitude for undergoing excitation and the value of *I* probably has general significance, and thus applies to most, if not all, substances. (c) These quantum mechanical properties of atoms and molecules have been implicitly disregarded in previous calculations of the action of ionizing radiations, because of certain simplifications made in those calculations; hence arose the disagreement with experimental facts.

#### CHROMOSOME BREAKAGE AND RECOMBINATION

Breaks may be induced in the chromosomes of mature sperm of *Drosophila* by

exposing adult males to X radiation. The potential breaks so induced are not utilized in the formation of new chromosomal arrangements, such as inversions and reciprocal translocations, until after the sperm has entered the egg (see Year Book No. 39). Since irradiated males may be kept for several days before copulation, a considerable period of time is available between irradiation and fertilization for efforts to alter experimentally the recombination capacity of the broken ends of the sperm chromosomes. The induced rearrangements are detected by analysis of the salivary glands of the larval progeny of the irradiated fathers. The percentage of glands showing rearrangements, and the nature of the rearrangements, were determined in earlier experiments for several X-ray dosage levels. For instance, at 4000 r about 29 per cent of the glands reveal chromosomal aberrations, and about 83 breaks occur in every 100 treated sperms. Any post-irradiation treatment that prevents the broken ends from forming new combinations should give appreciably lower values than those of the X-ray controls, and any treatment that fosters recombination should produce either a greater proportion of altered sperms or more complex rearrangements. The first experiments along these lines, made by Dr. Kaufmann and Dr. Hollaender, were outlined in Year Book No. 41.

In continuation of this work, two types of experiment were designed. Efforts were made, first, to modify the potential breaks produced by X rays in the quiescent chromosomes of the sperm by further treatment of the adult males containing these sperms, and, second, to alter the capacity of broken ends to recombine by varying the temperature during the period when the male pronucleus is being organized and its chromosomes are presumably offered opportunities for establishing new combinations. In this work the extensive

biological analysis has been carried out by Dr. Kaufmann; and Dr. Hollaender has supervised the treatment with ultraviolet and near infrared rays.

As reported in Year Book No. 41, exposure of X-rayed males for extended periods of time to near infrared radiation results in an appreciable decrease in the frequency of detectable chromosomal rearrangements as compared with the controls. When, however, females were exposed to near infrared radiation for periods ranging from 72 to 216 hours after insemination by males that had been treated with 4000 r of X rays, there was a much smaller decrease in break frequency with increasing exposure. Further analysis of data obtained following infrared treatment of X-rayed males suggests that reduction in the number of detectable chromosomal breaks may not be attributable solely to "healing" or incapacitation of broken ends, but that prolonged exposure to the near infrared rays may accelerate the rate at which germ cells that were immature and not affected by X-ray treatment are converted into mature sperm. In either case, the proportion of normal sperms transferred in copulation will be increased, and the frequency of detectable rearrangements found among the  $F_1$  salivary-gland chromosomes will be correspondingly lowered.

Other males were exposed to ultraviolet radiation of wave length 2537 Å after X-ray treatment of 4000 r. Only 10 males could be exposed simultaneously to the ultraviolet, so that small numbers of progeny were obtained in each experiment and variability from experiment to experiment was considerable. The over-all effect, obtained from an analysis of 289 pairs of glands, was a slight reduction from the 4000-r control value in the percentage of altered sperms (to 23 per cent), and a much greater decrease (to 58 per cent) in the frequency of breaks. This latter effect was brought about largely through elimi-

nation of the more complex rearrangements. It has been suggested by C. P. Swanson that ultraviolet radiation of wave length 2537 Å has a pronounced effect on the matrix materials of the plant chromosome; and some such disturbance may occur in *Drosophila*, although work with various other wave lengths will be necessary to check this hypothesis.

Efforts to affect the recombination properties of broken chromosome ends during the time of organization of the male pronucleus involved exposure of the inseminated females to incubator temperatures of either 18° or 28° C., or to the heating effects of the near infrared rays. The complete data from these experiments have not been assembled; but analysis of about 150 pairs of glands obtained after each type of treatment shows that both the near infrared and the 28° temperature give percentages of altered sperms and total breaks slightly higher than the controls, whereas the frequency of breaks at the 18° temperature is somewhat lower. Since all cultures of flies were raised under similar conditions following the period of egg-laying, it would seem that the higher temperatures facilitate those chromosome movements that lead to the production of contacts between the broken ends of the chromosomes.

The discovery by Dr. Kaufmann, reported in Year Book No. 41, of an exceedingly complex X-ray-induced chromosomal rearrangement involving at least 32 breaks has led to a revision of previous ideas concerning the mechanism of induction of complex rearrangements in *Drosophila* sperms. This mechanism is known to involve two stages: in the first stage, at the time of irradiation, sperm chromosomes are broken, actually or potentially; but the recombination of broken fragments to form a "rearranged" chromosomal complement occurs as a second stage, at the time of fertilization, when the male pro-

nucleus begins to open up in the egg. For the sake of simplicity, it has heretofore been assumed that, whereas the first stage is characterized by the active influence of radiation, recombination is substantially a passive phenomenon; specifically, that the rejoining of one or more pairs of broken ends during recombination does not affect the fate of other broken ends except by reducing the number of broken ends available for further recombination.

It was pointed out by Dr. Fano at the 1941 Cold Spring Harbor Symposium that the relative frequency of simple and complex rearrangements cannot easily be reconciled with this assumption. In his opinion, Dr. Kaufmann's discovery now furnishes additional and decisive grounds for discarding the assumption and investigating the implications of the existing evidence on complex rearrangements. This investigation cannot proceed through unequivocal logical deductions, but the conclusions reached indicate that breaks become more readily available to take part in a rearrangement after the rearrangement begins to develop from other breaks. The simplest possible mechanism that can be postulated to explain this circumstance is the following: A large number of potential breaks is produced by the usual X-ray treatment; each break has a chance of healing that is originally large but that can be substantially lessened by some mechanical perturbation (e.g., a pull along a chromosome) arising after fertilization when a rearrangement happens to be started by two other breaks. The possibility that some of the breaks involved in complex rearrangements are not produced initially by radiation, but arise as secondary effects due to recombination of other breaks, should also be considered, in view of the fact that the relative frequency of simple and complex rearrangements changes little with increasing radiation dosage.

## MAIZE GENETICS

BARBARA McCLINTOCK

## STUDIES WITH BROKEN CHROMOSOMES

For several years, the behavior of chromosomes having a single broken end has been investigated. In all cases, the original break was induced at meiotic anaphases following crossing over between the homologues of chromosome 9, one of which is structurally modified. The primary purpose of this study was to determine the behavior of the broken end in subsequent nuclear generations, and this was fulfilled in establishing the chromatid type of breakage-fusion-bridge cycle in the gametophyte and endosperm tissues and the chromosomal type of breakage-fusion-bridge cycle in the sporophytic tissues. From these studies, material was obtained for other investigations, some of which were mentioned in last year's report, and which have been expanded during the year. Several incidental observations arising from them will be mentioned.

To continue these studies, a method of producing large numbers of functional gametes each containing a chromosome with a single, unsaturated broken end was desired. This was accomplished by partial elimination of the undesirable male gametes through differential pollen-tube growth which favored grains having a chromosome with a broken end. Plants that are heterozygous for a normal chromosome 9 and a chromosome 9 with a duplication of the short arm give rise to gametes having either a normal chromosome 9, a duplication chromosome 9, or a broken chromosome 9 (following a cross-over involving the duplicated segment). Although cytological observations indicate that 18 per cent of the spores carry a broken chromosome, only 3.6 per cent are recovered from the pollen of these plants. Presumably because of chromosomal unbal-

ance, pollen with the duplication does not compete well with pollen carrying a normal chromosome 9. Consequently, the pollen grain that mainly functions carries the normal chromosome 9. If, however, in such plants, the normal chromosome 9 is replaced by a chromosome 9 with a non-male-transmissible deficiency, only the pollen grains with a duplication or a recently broken chromosome can function. Competitive pollen-tube growth now favors those grains which carry a broken chromosome 9, because the chromosome 9 constitution in many of these grains is less unbalanced than in those carrying the duplication chromosome. If a large amount of pollen from such plants is placed on silks, pollen grains carrying broken chromosomes will function successfully in 75 to 90 per cent of the cases. This is a tremendous increase over the previously available 3.6 per cent. These figures are based on tests of nearly 30,000 pollen grains.

The chromatid type of breakage-fusion-bridge cycle occurring in the gametophyte divisions following a meiotic breakage of chromosome 9 can result in gametes carrying various degrees of deficiency and duplication of the short arm of chromosome 9. Kernels whose embryos have multiple duplications of the short arm can be identified on a genetic basis. Therefore, many individual kernels were isolated and the plants arising from them examined. Comparisons of plants that are monosomic, disomic, trisomic, tetrasomic, and pentasomic for the full short arm of chromosome 9 show no striking changes in growth or morphology that could be attributed to chromosomal unbalance.

An unusual type of chromosomal translocation involving chromosome 9, men-

tioned briefly in last year's report, has continued to appear. All such translocations were found in plants which had received a recently broken chromosome 9 from one parent. In all cases, only one translocated chromosome was present. It was composed of the long arm of chromosome 9 and a single arm of another chromosome of the complement, united at their centromere regions. The short arm of chromosome 9 and the complementary arm of the second chromosome were missing. The frequency and complete similarity in all cases of this unusual type of translocation suggest a particular type of action on the part of the chromosome 9 that is undergoing the breakage-fusion-bridge cycle. This cycle frequently produces a telocentric chromosome composed of the long arm of chromosome 9. The hypothesis is suggested that the newly produced terminal centromere fuses with a centromere of any one of the other chromosomes of the complement. This configuration eventually results in the elimination of one chromosome arm of the tripartite complex.

In last year's report, the identification of kernels that had received a chromosome with a single broken end from each gamete nucleus was described. Twenty such kernels were sown, and the seedlings arising from half of these showed that fusion had occurred between the two broken ends contributed by each gamete nucleus. In the remaining 10 plants, no evidence of such fusions was seen. To interpret more adequately the subsequent behavior of these two chromosomes, a larger sample was desired. Through the improved method of obtaining functional male gametes whose nuclei contain a chromosome 9 with a single broken end, several hundred kernels of the desired type were readily obtained. Among 138 such kernels selected for testing, 108 produced seedlings. The embryos in the remaining 30 were

morphologically aberrant and were unable to grow. Among the 108 viable plants arising from these kernels, 72 gave evidence of fusion between the broken ends of the chromosomes 9 contributed by the two gametes. No evidence of such fusion was obtained from the remaining 36 plants. This does not mean that no fusions had occurred, for the subsequent behavior of the dicentric chromosome arising from such fusions could quickly nullify all evidence of fusion in the later nuclear divisions, which are the ones examined for this evidence. The behavior of the dicentric chromosome follows two main courses. During nuclear division, the two centromeres of each dicentric chromatid may pass to opposite poles in a spindle figure, producing two contiguous chromatin bridges stretched between the poles. When rupture of these two bridges occurs during late anaphase or early telophase, two newly broken ends enter each sister telophase nucleus. Fusion may then occur between these broken ends, re-establishing the dicentric chromosome condition and the chromosomal type of breakage-fusion-bridge cycle.

The second course that the dicentric chromosome may follow results in absence of fusion between the two broken ends in the nuclei that arise following the formation of such anaphase bridges. These two broken ends, which are observed in the nuclei of later generations, are permanently healed; for no subsequent fusions occur. Observational evidence strongly suggests that the healing process may be related to the nuclear cycle; that is, if a recently broken (unsaturated) end enters a telophase nucleus and has no other unsaturated end with which it may fuse, it will "heal" and become saturated or incapable of fusion during the period from telophase to the following prophase or during the reproductive cycle of the chromo-



some. The evidence leading to such an interpretation derives from the frequent observation of sister nuclei that are connected by a single chromatin bridge during late telophase and interphase. This would result if only one of the two contiguous bridges were ruptured during anaphase or early telophase. In that case, a single bridge would connect the two sister nuclei, and only one unsaturated broken end would have entered each nucleus. It is known that in sporophytic tissues such a single broken end will heal. If the single chromatin bridge connecting the two nuclei is not broken until the following prophase, the single unsaturated broken end within each nucleus may have healed. The second broken end, which will enter each nucleus following eventual rupture of the hitherto persistent bridge, may then have no unsaturated end with which it may fuse. It, in turn, will heal. The dicentric chromosome cycle is terminated and each nucleus has two broken ends, which, however, are saturated and incapable of further fusions. The nature of the healing process is not known; if, as this evidence suggests, it is related to the chromosome division cycle, experiments should be focused on this period.

#### TESTS OF THE AMOUNT OF CROSSING OVER THAT MAY OCCUR WITHIN SMALL SEGMENTS OF A CHROMOSOME

Previous investigations have placed the locus of the mutant *yg-2* within the terminal chromomere of the short arm of chromosome 9. Rhoades had determined that the mutant *Dt* is located 7 crossover units beyond *yg-2*. This suggests that a relatively high percentage of crossing over must occur within a minute distal segment of the chromosome. To obtain some evidence on the amounts of crossing over that may occur within specific small regions,

the following method was used. Plants were made heterozygous for terminal deficiencies of the short arm of chromosome 9. The extent of the deficiencies ranged from loss of the terminal chromomere to loss of four chromomeres. The normal chromosome 9 carried the recessive mutant *c*, and the deficient chromosome the allele *C* (*C*, colored aleurone; *c*, colorless aleurone). *C* is located within the fifth or sixth chromomere from the end of the short arm of chromosome 9. When pollen of such plants is placed on silks of plants homozygous for *c*, only the pollen grains carrying the normal chromosome 9 will function. Therefore, any *C* kernel that appears is the result of a crossover in the segment between the locus of *C* and the end of the deficient chromosome. The proportion of *C* to *c* kernels is thus a direct measure of the amount of crossing over that occurs within this segment. As the deficiency becomes shorter, the proportion of *C* to *c* kernels increases. The difference may be ascribed to the increasing length of the segment in which crossing over may occur. Since the increase of each segment is known, the amount of crossing over ascribable to this increment may be determined. The 11 deficiencies tested have been placed in five groups of descending order of length. Cytological observations of the exact position of a break that gives rise to a terminal deficiency are extremely difficult, because of the minute size of the chromomeres. Any one deficiency, placed in a particular size group, may be plus or minus a small part of a chromomere.

The table on page 151 shows that as the segment in which crossing over is measured becomes progressively longer, marked increases in crossing over occur. Toward the end of the series, an increase of half a chromomere may increase the crossover units by 10. Thus, if *yg-2* is lo-

cated toward the middle of the terminal chromomere, the location of *Dt* seven cross-

Deficiency	Per cent crossing over	No. of kernels examined
Deficient for 4 chromomeres:		
df 1297A-2.....	0.016	6130
df 1278A-4.....	0.052	1923
df 1501A.....	0.52	5748
df 1559B-2.....	0.72	1383
df 1463-2.....	0.94	9743
Deficient for 3 chromomeres:		
df 1265.....	1.25	5830
Deficient for 2 chromomeres:		
df 1533A.....	3.07	8791
Deficient for 1½ chromomeres:		
df 1507.....	8.33	4566
Deficient for 1 chromomere:		
df 1509.....	17.06	3826
df 1512D-2.....	21.1	1639

over units beyond *yg-2* is not necessarily cytologically inconsistent. Since the normal amount of crossing over between *C* and *yg-2* is only 19 per cent, it is highly probable that crossing over toward the tip of this arm is considerably more frequent per unit physical length than in other parts of the arm.

#### DEFICIENCY MUTATIONS: PROGRESSIVE DEFICIENCY AS A CAUSE OF ALLELIC SERIES

During the past year, major emphasis has been placed on expanding the studies of mutations associated with small terminal deficiencies of the short arm of chromosome 9. All such deficiencies originate from chromosomes that are broken during meiosis, as was explained earlier in this report. The short arm of the normal chromosome 9 terminates in a knob. A relatively thin chromatic thread connects this knob with the first distinct chromomere of the short arm. If a break occurs adjacent to the distal part of this first chromomere, a chromosome 9 deficient for

the "stalk" of the knob results. Gametes having this deficiency are completely functional. Embryos homozygous for this deficiency are normal; but the seedlings, although normal in growth rate and morphology, are pale yellow and incapable of continued growth because of the defective chlorophyll condition. Because newly produced broken chromosomes 9 can be obtained in large numbers, this deficiency mutant has been produced repeatedly and independently in unrelated strains whenever the short arm of chromosome 9 is subjected to breakage, regardless of the method that produces this breakage. Seven unrelated and independently produced deficiency pale-yellow mutants have been selected for intensive study. When the stalk of the knob and approximately half of the terminal chromomere of the short arm of chromosome 9 is removed during breakage, the male and female gametes containing this deficient chromosome are functional. In the homozygous condition, this deficiency produces not pale-yellow but white seedlings. These seedlings are dwarfed, although their general morphological development appears to be normal. As with the pale-yellow mutants, the white-seedling mutants have occurred repeatedly in the progeny of independently produced broken chromosomes. Six of these mutants have been isolated for intensive study.

The allelic relations of all these mutants are being tested. Of the 21 possible combinations of the 7 pale-yellow mutants, 13 have been tested. Complete allelomorphism has been observed with all 13. Although tests of all individual combinations have not been completed, the types of combination that have been tested indicate complete allelism of all 7 mutants. These tests indicate that all pale-yellow deficiency mutants are similar in their character expression. Combinations to test the allelic relations of the white mutants have been made, but the

seedling tests have been completed on only 3 of the 15 possible combinations. In these 3 cases white seedlings appeared, indicating the allelic nature of the whites. The pale-yellow mutants have been combined with the white mutants. Of the 42 possible combinations, 14 have been tested. All 14 combinations gave rise to pale-yellow seedlings identical in appearance with the homozygous pale-yellow mutant type. The combinations so far tested have established this relationship for 5 of the 6 white mutants. It may be concluded, therefore, that the deficiency pale-yellow mutants are completely dominant to the deficiency white mutants.

Previous investigations had suggested that the well known and frequently used recessive mutant *yg-2* (yellow-green plants) has its locus within the terminal chromosome of the short arm of chromosome 9. To determine the relation between *yg-2* and these deficiency mutants, crosses have been made with all 13 deficiency mutants. Combinations of 6 of the 7 pale-yellow mutants with *yg-2* have been tested. In all 6 cases, only normal green seedlings were produced. The deficiency pale-yellow mutant and *yg-2* are not allelic. Combinations of the deficiency white mutants with *yg-2* gave entirely different results. Although only 3 of the 6 combinations have been tested, all 3 combinations gave rise to *yg-2* plants. This indicates the allelic relations of the deficiency white mutants and *yg-2*. Yellow-green-2 is dominant over deficiency white.

The combined results throw an interesting light on the nature of one form of allelism which would be puzzling to interpret if the cytology were not known. The cytological analysis allows a logical interpretation to be made. The allelic

relationships may be represented by two series of descending order of dominance:

1. Normal green  $\rightarrow$  pale-yellow  $\rightarrow$  white
2. Normal green  $\rightarrow$  *yg-2*  $\rightarrow$  white

Although the two series have a mutant in common, pale-yellow  $\times$  *yg-2* gives only normal green plants.

The interpretation of progressive deficiency will explain these results completely. Normal green plants have an unmodified chromosome 9, carrying *Yg-2*. This chromosome will cover any deficiency in a homologue and likewise the recessive mutant *yg-2*. The deficiency which produces pale-yellow is short and does not include the locus of *Yg-2*. Therefore, the chromosome carrying *yg-2* covers the pale-yellow deficiency, whereas the deficient pale-yellow chromosome carries the dominant allele of *yg-2*. Thus only normal green plants result from this combination. It is cytologically obvious that the chromosomes 9 producing the white mutants have a longer deficiency than those producing the pale-yellow mutants. If it is assumed that the deficiency producing the white mutants includes the locus of *Yg-2*, the removal of this locus would allow *yg-2* to be expressed when the *yg-2* chromosome is combined with the deficient chromosomes 9 producing the white mutants. Only *yg-2* will appear, for the chromosome carrying *yg-2* will cover the deficiency present in the chromosome producing the white mutant. Progressive deficiency, therefore, will completely explain the allelic relations which these mutants show with each other and with *yg-2*.

Because newly broken chromosomes 9 give rise to these same mutants over and over again, studies are now in progress to determine the "mutation" rates.

## POLYPLOIDY INVESTIGATIONS

H. E. WARMKE AND HARRIET DAVIDSON

The work of this laboratory continues to be devoted largely to projects related to the war effort. These for the most part are practical and immediate in nature and represent work which, because of our facilities and training, we are especially qualified to undertake. They have been initiated at the suggestion of the Department of Agriculture, Bureau of Plant Industry, and carried on with the active cooperation of that Bureau.

## RUSSIAN DANDELION

Our original investigation on this species, concerning cytology and breeding behavior, was completed and published during the year. In addition to the studies reported last year, it has been found that fertilization is extremely rapid, occurring some 30 minutes after pollination, and that it follows the normal sexual pattern, one male nucleus uniting with the egg and one with the primary endosperm. Chromosome counts of  $2n=16$  in the developing embryo and  $3n=24$  in the dividing endosperm cells verify the reality of the entire sexual process.

Studies on self-sterility were continued, and have revealed a high degree of "end-season fertility." Many of the greenhouse plants, which were protected from insects and failed to set selfed seed during the spring and summer, set abundant seed in November and December.

*Distribution of latex in the root.* During the year new studies on the Russian dandelion were undertaken at the request of the Department of Agriculture. These relate to the anatomy of the root, and were planned as an aid in sampling roots for comparative rubber analysis. In making rubber analyses in the various selection and breeding programs being carried on

throughout the country, it is important to know whether the part of the root used in sampling is of any consequence, and if so which part should be used. In the past, small samples of 100 to 300 mg. in weight have been used, and these often have not been chosen with particular care as to position.

A technique was developed in this laboratory, using osmic acid as a fixing and staining agent, by which the rubber-containing latex vessels could be sharply differentiated from the parenchyma cells in root sections, and the whole preserved in permanent mounts. Sections prepared in this manner and taken at half-inch intervals between the crown and tip of the root were projected on paper; and with a planimeter the total latex area and percentage of latex in each section were calculated. The graph shown in figure 2 gives average latex percentages for different parts of the roots of 12 plants studied in this way.

In all cases there is a definite and regular increase in latex percentage with increase in distance from the crown. In many instances the variation in latex content at different levels of a single root exceeds the variation between plants. In seeking real differences between plants for breeding purposes, therefore, the part of the root used in sampling is obviously of the greatest importance. These data have been made available to the Department of Agriculture, together with a recommendation that larger samples, covering most of the length of the root, be used in chemical analyses.

*Polyploidy and rubber content.* Our studies on experimental polyploidy in the dandelion, which had just begun at this time last year, are progressing satisfactorily. Seeds have been obtained from crosses be-

tween colchicine-treated plants, and from these a large number of first-generation autopolyploids, including both tetraploids and triploids, have been grown. The tetraploids are strikingly more robust than the diploids from which they were derived:

tance, because among the many reported natural polyploid species within the genus (triploid, tetraploid, and pentaploid), sexual reproduction has been replaced by a type of apomictic development, in which an unreduced egg starts development with-

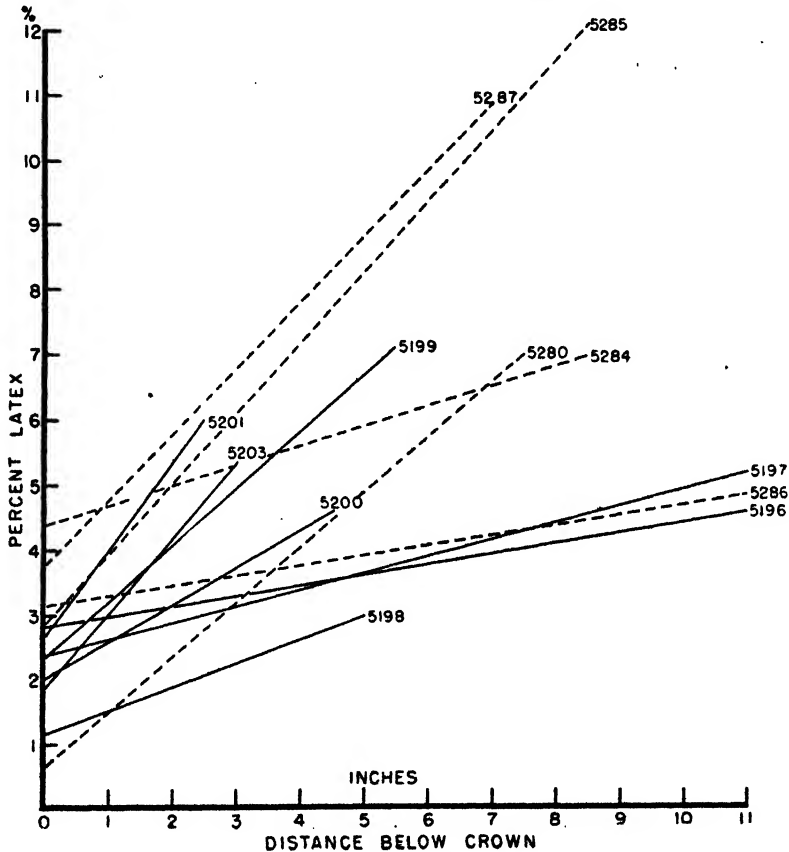


FIG. 2. The relation of position to latex percentage in 12 roots of the Russian dandelion as calculated from area measurements of sections. Solid lines indicate greenhouse plants, and broken lines indicate field plants.

leaves are thicker, greener, and broader, and thus present more leaf area for photosynthetic activity. The flowers and flower stalks show a corresponding increase in dimensions; pollen is good, and the set of seed is high. The normal self-sterility and sexual behavior of the diploid, however, apparently are retained in the experimental tetraploids. This is of considerable impor-

out the stimulus of fertilization. Among the experimental plants, however, even the triploids, which are largely sterile because of irregular chromosome distribution, fail to develop apomictic reproduction.

Samples of 20 diploid and 20 tetraploid roots, of the same age and grown under similar conditions, have shown the tetraploid to be significantly heavier. The fresh

tetraploid roots weighed on an average  $10.64 \pm 0.85$  grams, and the fresh diploid roots  $8.17 \pm 0.70$  grams. Since the root is the rubber-bearing organ, this increase in weight, if borne out by larger samplings and if not accompanied by a corresponding decrease in rubber concentration, may be of importance in the commercial development of the species. The diploid and tetraploid root samples have been dried and sent to the rubber-testing laboratory at Beltsville, Maryland, for accurate comparative rubber determinations.

### HEMP

*Marihuana studies.* Our efforts to produce a fiber hemp with low marihuana content are continuing. It has been possible to accelerate the program by growing a second generation in the greenhouse in winter in addition to the regular summer crop. The previous assay method, utilizing *Fundulus*, which is available only in the summer, was adapted to the use of the water flea, *Daphnia*, which can be grown in the laboratory the year round. *Daphnia* has other advantages: (1) parthenogenetic reproduction provides genetically uniform offspring, (2) laboratory culture makes it possible to control accurately the ages of test animals, and (3) their smaller size makes testing of smaller leaf samples practicable. These studies using *Daphnia* in the assay of marihuana have been carried on in cooperation with Dr. A. M. Banta, of Brown University.

In Year Book No. 41 wide differences in the marihuana content of individual plants were noted; but whether these were largely the result of genetic or of environmental variables could not be stated. The summer tests, which have just been completed, give evidence that marihuana content is influenced by heredity.

Ten pedigrees of plants were grown

from parents selected and intercrossed because of low marihuana content, and ten pedigrees were grown from parents selected because of high marihuana content. The results of drug determinations on these two groups of pedigrees are presented graphically in figure 3. The 147 plants tested from high-marihuana parents killed an average of  $5.82 \pm 0.14$  animals; 235 plants from among those having low-marihuana parents killed an average of only  $4.99 \pm 0.12$  animals. This is a significant difference after only one generation of selection, and further divergence seems likely with continued breeding.

Of equal importance from a practical point of view is the fact that among the offspring of low-content parents there were 22 plants that killed no more than 2 animals, whereas among the offspring of high-content parents only 2 such plants were found; correspondingly, the high pedigrees produced 9 plants that killed 9 or more animals, whereas the low pedigrees produced no individuals so potent as this. These extreme low and high types have been isolated and intercrossed, and their offspring will be tested during the coming winter.

The fact that the marihuana content is higher in plants from the same pedigree when grown in the greenhouse than when grown out of doors indicates that environmental factors also play a role in marihuana synthesis and storage.

*Polyploidy in hemp.* Reports have been received from the Department of Agriculture on comparative fiber yields of the original diploid and tetraploid strains submitted by this laboratory. These show no significant superiority of the tetraploid over the diploid. It seems, however, that sufficient consideration was not given, when plantings were made, to the greater weight of the tetraploid seed. As a result, tetraploid test plots had fewer plants per square

foot than diploid plots, and may therefore have been placed at a disadvantage in yield comparisons. For this reason, it is planned to submit more samples of diploid and tetraploid seed for further yield tests. In addition to our original strain, we now have three other tetraploid stocks, which have been derived from superior fiber stocks furnished us by the Department of Agriculture.

diploid offspring from such crosses killed an average of  $5.53 \pm 0.27$  animals; 10 triploid offspring killed an average of  $6.20 \pm 0.90$  animals; and 69 tetraploid offspring killed an average of  $7.57 \pm 0.31$  animals. These results, obtained with substantially improved techniques, confirm the greater marihuana potency of the polyploid types over the diploids, reported in a preliminary fashion last year.

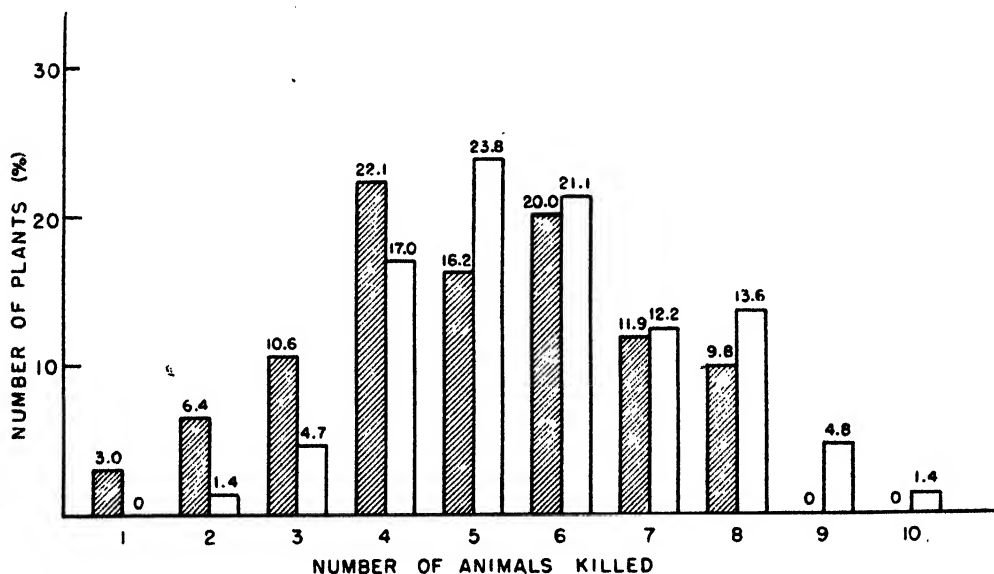


FIG. 3. The effect of heredity on marihuana content in hemp, as revealed after one generation of selection. Crosshatched bars show distribution of marihuana potencies among 235 offspring of selected low-content parents; open bars show marihuana potencies of 147 offspring of selected high-content parents. Plants that kill a small number of animals have low potency; those that kill a large number of animals have high potency.

Tests begun last year on the relative marihuana content of polyploids of different degree have been continued. Genic differences have been reduced to a minimum by testing diploid, triploid, and tetraploid plants from the same male and female parents. Such stocks were secured by intercrossing colchicine-treated plants in pairs. Some of these pairs proved to have mixed  $2n$  and  $4n$  germinal tissues, and produced the three polyploid types. Ninety

#### POLYPLOIDY AND PORE NUMBER IN MICROSPORES

In the routine examination of the large numbers of tetraploid forms produced in this laboratory, it has been observed that pollen of tetraploids tends to have a larger number of germ pores than the pollen of corresponding diploids, the increase from three to four germ pores being especially common. A few four-pored grains are normally found in the pollen of diploids,

and it has been the opinion of various workers that this increase in pore number results from a different arrangement of the four microspores within the wall of the microspore mother cell. It has been postulated that the three germ pores result from a tetrahedral arrangement of the spores in the tetrad, and that the four-pored condition results from a square or rhomboidal arrangement.

It seemed of interest—in this polyploid material, where the diploid may have as little as 1 per cent four-pored pollen and the tetraploid as high as 90 per cent, as in

*Nicotiana langsdorffii*—to observe the arrangement of microspores in the tetrad, and to determine whether the increase in pore number is accompanied by a corresponding increase in the number of square and rhomboidal tetrad arrangements. Preliminary studies by Dr. Kaeiser indicate that there is not sufficient difference in the arrangement of spores within the tetrads of the tetraploid to account for more than a fraction of the four-pored pollen grains observed, and suggest that factors other than tetrad arrangement are of importance in determining germ-pore number.

## ANTHROPOLOGY AND HUMAN GENETICS

MORRIS STEGGERDA AND HILDA H. WHEELER

### ANTHROPOMETRY

*Navajo Indians: adults.* Measurements of body dimensions were taken on 150 adult male and 100 adult female Navajo Indians living on the reservation in Arizona and New Mexico. These are compared with measurements on Maya Indians of Yucatan, Negroes of the British West Indies, and Dutch whites of Holland, Michigan, all groups on which Dr. Steggerda has made similar studies. The average age of the Navajos studied is 24.5 years for the males, with a range from 18 to 60, and 22 years for the females, who ranged from 18 to 50. Most of the individuals were young adults, but all had attained full stature. The results are given in the accompanying table.

The means for stature are close to a weighted average for Athapascans in general (a linguistic group to which the Navajos belong; see Steggerda, Carnegie Institution of Washington Publication 434), namely, 169.7 cm. and 156.6 cm. for males and females respectively. Hrdlička, in his study on Indians of the southwestern United States and northern Mexico, gives

MEANS AND PROBABLE ERRORS FOR SIX DIMENSIONS OF ADULT NAVAJO INDIANS

Dimension	Males	Females
Stature (cm.) . . . . .	168.04±0.28	155.50±0.31
Weight (kg.) . . . . .	59.51±0.39	53.66±0.42
Relative chest girth (%) . . . . .	53.04±0.16	53.24±0.20
Relative sitting height (%) . . . . .	52.75±0.06	53.31±0.08
Relative span (%) . . . . .	103.98±0.13	102.85±0.13
Cephalic index (%) . . . . .	85.31±0.22	85.32±0.32

means of 168.6 and 156.8 for a small number of Apaches and Navajos grouped together. Navajos are not among the tallest Indians (170–174.9 cm.) (see Pub. 434), but rather in the next lower category, 165–169.9 cm. The Jamaica Negroes averaged 170.6 cm., and the Dutch whites of Michigan 173.6 cm. The female-male index for Navajo stature is 0.925; this index for Negroes and whites is 0.928 and 0.935 respectively.

Relatively few studies have been made of the weights of racial groups, but those that are available show the Navajos to be rather light in weight. For example, the



Choctaws as described by Collins are only 2 cm. taller than the Navajos but weigh 8 kg. more. The Jamaica Negroes, who average 2.6 cm. more than the Navajos in height and are well known to be slender, average 6.5 kg. more in weight.

The Navajos are of a medium body build, similar to that of the Dutch whites in Michigan; both these groups have a relative chest girth of 53 per cent, as compared with the 49.9 per cent found for Negroes. The short Maya Indian males have a relative chest girth of 56 per cent. The sitting height of the Navajo males is 52.8 per cent of their stature, of Maya males 53.0 per cent, of Negro males 51.5 per cent, and of Dutch white males 52.3 per cent. The arms of the Navajo males are relatively long, with a mean relative span of 104 per cent; the span for Dutch whites is 103 per cent, for the Maya 104.6 per cent, and for the Negroes 106 per cent. The Navajo heads are brachycephalic, with an index of 85 per cent for the males; this is equal to that of the Maya males; the Dutch whites have an average index of 79 per cent and the Jamaica Negroes 77 per cent.

*Navajo Indians: children.* Individual curves of growth for approximately 75 Navajo females and 100 Navajo males have been plotted over a 10-year period. Deviations of these individuals from the average curves of growth based on hundreds of Navajos are being made. The rates of growth at various stages in their development are also being considered, and comparisons are being made with the growth and development of the three other racial groups studied by the author.

A detailed study of Navajo anthropometry is being made, considering 60 or more body dimensions of both adults and children, with comparisons of all available data.

#### ANTHROPOLOGY

*Maya Indians: milpa experiment.* The Maya Indians of Yucatan plant corn in the same field for only two or, at the most, three years in succession, then abandon that field and choose a new one for planting. The yield for each successive year in any field is smaller than for the preceding year. The reasons advanced to explain this decrease are: weed competition and the encroachment of grass, soil deterioration, and insect pests. The data collected by Steggerda over a 10-year period in Yucatan throw light on each one of these factors.

In January 1933, 15 mecates (1 mecate = 400 sq. m.) were selected for corn planting. The center mecate, number 8, was used as the experimental plot, and records were kept of its yield for each year. The entire 15 mecates were planted in corn, the 14 mecates surrounding mecate 8 serving as a possible protection against insects, birds, and mammals, which are believed to work in from the surrounding forests. Weeding was done at first by the Maya method alone, which consists of cutting off the weeds with a machete. The first two years, the field was weeded once each year; the next two years, it was necessary to weed twice each season. During these first four years of production, the yield of shelled corn from mecate 8 showed a progressive decline, as follows: 32, 28, 16, and 7 kg. Because of this decrease it was decided to weed mecate 8 more thoroughly in 1937, by pulling up the weeds instead of cutting them off. Beginning with this fifth year, the 7 mecates south and east of number 8 were kept relatively clear of weeds by pulling them out, and the 7 mecates to the north and west were weeded by the Maya method. From 1937 to 1942 the yields were recorded for all 15 mecates.

The records indicate that the yield of

mecate 8 fluctuated greatly. It may be significant that in the first year after the improved weeding method was introduced the yield was greater than it was in 1933. In the following year (1938), however, the yield was again decreased. It rose slightly in 1939; and, owing chiefly to a plague of grasshoppers, it fell to practically nothing in 1940. In 1941 the entire field had to be abandoned because of a grasshopper plague. In 1942 the yield was slightly less than for 1938.

The yields for the 14 mecates surrounding plot 8 during the years 1937-1942 show similar fluctuations. The fact that in 1937 and 1938 the 7 western mecates yielded more corn than the 7 eastern ones, even though they were weeded by the more primitive and less efficient method, may be due to better drainage or other environmental factors. In 1939 and 1940, however, the thoroughly weeded mecates 1 to 7 produced slightly more than mecates 9 to 15. A record of the time and money expended on the weeding of the fields shows that both increased as the experiment was prolonged.

In March 1941 a detailed survey was made of each mecate to show the amount and kinds of grass present. Samples of the grasses found were identified by Dr. P. C. Standley, of the Field Museum in Chicago, and include witch grass (*Panicum*), crab grass (*Digitaria*), millet grass and foxtail (*Setaria*), and the common sandbur (*Cenchrus*). During the first few years grasses were not present, but as the field continued in production it was gradually taken over by grass; and now after 10 years several of the mecates are completely covered with a heavy stand of grass. This cannot be controlled by the Maya, because it is impossible to use modern farming tools on account of the shallowness of the soil and the abundance of rocks.

Analyses of Yucatan soils by the U. S.

Department of Agriculture and the University of Illinois show nitrate and phosphate deficiencies which would definitely limit production. The Maya Indians do not apply fertilizer to their crops, although the ashes resulting from the burning of felled trees and cleared underbrush take its place to some extent. The fact, however, that no significant difference was found in the soil chemistry of samples from the continually cultivated fields and from uncultivated plots indicates that soil deterioration may be discounted as a factor in crop decline. Insects, no doubt, cause a considerable decrease in yield, since corn borers and leaf-cutting ants increase in numbers as a cornfield gets progressively older.

Obviously it is easier for the Indians to move their cornfields to a new location every two or three years than to combat weeds and insects in the old one. Since their present-day agricultural methods seem to be the same as those used in ancient times, the various factors discussed above may help explain why the ancient Maya abandoned their sites and migrated to new areas.

*"Enciclopedia yucateca."* During the year a 30-page report was written on the topic "Physical and physiological characteristics of the Maya Indians of Yucatan, Mexico." This was done at the request of Dr. Carlos A. Echanove, who has been put in charge of the compilation and publication of the "Encyclopedia of Yucatan" by the Governor of the State. The report prepared for this publication includes the anthropometry of Maya children and adults, and morphological and physiological observations such as eye color, hair color and form, blood pressure, blood groups, dental caries, and tooth-eruption time.

*South American Indians.* In 1940 Steggerda began a survey of the anthropometry and physical features of the South Ameri-

can Indians as recorded in the literature, for a forthcoming *Handbook* to be published by the Smithsonian Institution. The work has been concluded and summarized in three separate articles: "Anthropometry of South American Indians"; "Pigmentation and hair of South American Indians"; and "Mestizos of South America." A total of about 200 books on the anthropology of South American Indians has been reviewed, and information covering the physical characteristics and body measurements of 90 different tribes has been obtained. Abstracts of these books and

pamphlets, together with a complete list of anthropological papers on South American Indians, will form a separate publication. Though various writers have studied these Indians from the ethnological point of view, relatively few have carried out anthropometrical investigations. The data collected have been reproduced in tables, grouping the tribes according to regional areas and also according to height classes. Contour maps have been prepared to show graphically the distribution of the stature groups, and a similar map shows the distribution of cephalic index.

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# NUTRITION LABORATORY

*Boston, Massachusetts*

THORNE M. CARPENTER, *Director*

The activities of the Nutrition Laboratory during the year have been restricted almost entirely to the war research projects that are being carried on in cooperation with the Harvard School of Public Health. The investigation which started on January 1, 1942 is still in progress. Apparatus have been devised and data have been accumulated that deal with important aspects of human physiology. When and if released for publication, these methods and physiological results will prove of value to all other workers in the same fields, as it will be possible to obtain data not previously accessible. It is fortunate that war emergency requirements have resulted in such real scientific advancement in human physiology.

In addition to the defense activities of the staff itself, a special project in connection with the war is in progress in space made available to Dr. J. H. Mueller, of the Department of Bacteriology and Immunology of the Harvard Medical School. Since December 1942, two laboratory rooms have been occupied exclusively by Dr. Mueller and his staff, and the Carnegie Institution of Washington has supplied the necessary utilities such as gas, water, heat, and electrical power for the carrying on of his work. This project is entirely independent of the regular activities of the Nutrition Laboratory.

## METABOLISM IN DIABETES MELLITUS

The investigation on the gaseous exchange in diabetes has continued this year under a special grant from the Carnegie Institution, with the active cooperation of Dr. Elliott P. Joslin and Dr. Howard F.

Root, of the New England Deaconess Hospital. Eighty-eight diabetic patients had their metabolism measured on 138 days. In addition, 10 nondiabetic patients were studied on 13 days for comparative purposes. The measurements included observations on the basal metabolism and on the metabolic effect of ingestion of 50 grams of dextrose or of levulose, with or without insulin simultaneously administered. Since about the first of December 1942, blood samples have been taken from most of the patients under basal conditions and again approximately  $\frac{1}{2}$  hour, 1 hour, and 2 hours after administration of the sugar, and these have been analyzed for their sugar, pyruvic acid, and lactic acid contents. Dr. Elmer Stotz, of the McLean Hospital, Waverley, Massachusetts, has cooperated in making these blood analyses. Comparisons have been made of the basal metabolism and carbohydrate metabolism of diabetic and nondiabetic individuals as affected by hyperthyroidism. Studies have likewise been made of diabetics having such complications as acidosis, coma, adenoma of the thyroid, pituitary tumor, and hypoglycemia. On November 29, 1942, with the cooperation of Dr. Robley D. Evans, of the Massachusetts Institute of Technology, observations were made on 10 diabetic patients and 5 normal controls, to study the rate of absorption of 25 units of radioactive insulin with respect to different types of patient. The respiratory exchange measurements were made by Jeannette F. Rayner on a full-time basis from July 1, 1942 to March 1, 1943, and thereafter on a half-time basis until June 30, 1943.

## STAFF NOTES

On January 15, 1943, Dr. Carpenter was appointed an official investigator of Section 11.2 of Division 11 of the National Defense Research Committee. On February 1, 1943, he was appointed Special Research Associate of Harvard University. On November 20, 1942, he gave his annual lecture on basal metabolism to the first-year class of the Harvard Medical School.

Robert C. Lee, having completed the academic requirements, was given the degree of Master of Arts by Boston University at its annual commencement exercises on May 24, 1942.

Mrs. Mary F. Schroader was appointed

laboratory technician on a part-time basis, on March 11, 1943.

Throughout the year Robert C. Lee, George Lee, and V. Coropatchinsky have devoted their entire time to war research projects, and Dr. Carpenter has given about half his time to these activities. Miss Elsie A. Wilson has used about one and one-half months of her time on the preparation and editing of reports to the Office of Scientific Research and Development.

The number of scientists and especially men in the service who have visited the Nutrition Laboratory for consultation and in connection with war research has been larger this year than in past years.

## LITERARY WORK

Definitions have been prepared by Dr. Carpenter for a "Dictionary of dietetics" that is to be published by the Philosophical Library, Inc., New York City. These definitions include terms that are in common use in reports on energy transformation and intermediary metabolism.

The following articles have been completed for publication in scientific journals:

"Partial pressures of carbon dioxide and oxygen in expired air and alveolar air when oxygen is breathed at different atmospheric pressures," by Thorne M. Carpenter and Robert C. Lee. (Accepted for publication in the *Journal of Aviation Medicine*.)

"Human respiratory quotients in relation to alveolar carbon dioxide and blood lactic acid after ingestion of glucose, fructose, or galactose," by H. T. Edwards, E. H. Bensley, D. B. Dill, and T. M. Carpenter.

"The absorption of radioactive insulin in human diabetes," by H. F. Root, J. W. Irvine, Jr., R. D. Evans, T. M. Carpenter, and L. Reiner.

Miss Elsie A. Wilson has had an efficient and active part in the calculations and editorial preparation both of these manuscripts and of the publications listed below.

## PUBLICATIONS

- (1) *An apparatus for measuring air flow during inspiration*. Robert C. Lee and Leslie Silverman. *Rev. Sci. Instr.*, vol. 14, pp. 174-181 (1943).

For measurement of the rate of flow of air during inspiration, an instrument offering no appreciable resistance to air flow has been devised, in cooperation with the Harvard School of Public Health. In principle, this

instrument employs as a measure of flow the displacement of a fine wire in an air stream with a uniform velocity profile. A microscopic platinum wire, suspended on a metal frame, is connected at one end with a small, light tension spring and is attached at the other end to a fixed point. The upper and lower parts of the wire are enclosed in metal ducts. The middle part passes through a

metal tube, fastened horizontally to the frame, and is visible through holes in this tube. The displacement of the wire by flow of air through the tube is magnified optically and recorded photographically by a moving paper camera. The deflection of the wire is linear with air flow, and its inertia, lag, and frequency of vibration do not interfere with respiratory measurements. Two specially designed low-resistance tubular valves and a metabolism mask complete the apparatus. Flow records and gasometer measurements obtained simultaneously with three subjects at rest and while riding a bicycle ergometer at different rates showed close agreement, the average deviation of flow record from gasometer record being 2.1 per cent.

- (2) *Methods of stating dosage of alcohol and concentration of alcohol in tissues.* Thorne M. Carpenter. *Quart. Jour. Studies on Alcohol*, vol. 3, pp. 165-167 (1942).

This is an editorial, which emphasizes the importance of exactness in statements regarding dosage and concentration of alcohol in tissues and fluids, to avoid confusion when comparisons are made between the results of different experimental findings.

- (3) *The effect of glucose administration in diabetic acidosis.* Howard F. Root and Thorne M. Carpenter. *Amer. Jour. Med. Sci.*, vol. 206, pp. 234-243 (1943).

According to observations on the respiratory quotient, the carbohydrate combustion of

patients in diabetic coma is not increased by administration of glucose either intravenously or by mouth. The use of insulin alone in early diabetic acidosis increases carbohydrate combustion. Even with insulin administration, however, not more than 10 grams of carbohydrate can be or need be oxidized per hour to reduce the rate of fat metabolism and hence to check the formation of ketone bodies. Administration of large amounts of glucose is ineffective in diabetic acidosis and may be harmful in that the rise in blood sugar produced by glucose will make it difficult to determine from changes in blood sugar the required insulin dosages, such excessive hyperglycemia is harmful to the pancreas, excessive glucose concentration in blood and tissues may result in anuria, and excessive glucose administration may lead to damage to the liver. These harmful effects may be concealed in early diabetic coma by the favorable effects of insulin simultaneously given. Moderate coma may be converted by glucose administration into severe coma requiring excessive insulin dosage. In advanced coma, glucose administration may precipitate the final stage of anuria. The object of treatment in diabetic coma is to restore normal utilization of carbohydrate by administration of the requisite amount of insulin. By this means the excessive amounts of glucose in blood and tissue fluids are oxidized or stored, liver glycogen is replenished, and excessive ketosis is reduced by the decrease in rate of total metabolism and in rate of fat metabolism.

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## SPECIAL PROJECTS: BIOLOGICAL SCIENCES

W. E. CASTLE, University of California, Berkeley, California. *Experimental studies of heredity in small mammals*. (For previous reports see Year Books Nos. 3 to 38, 40, and 41.)

Investigations of genetic linkage in the rat carried on in collaboration with Dr. Helen Dean King, of the Wistar Institute, have in the past year yielded two positive results. The order of the four mutant genes located in chromosome II has been found to be

$$\frac{Cu \text{ } an \text{ } in \text{ } b}{0 \quad 4 \quad 8 \quad 45}$$

and the map distances approximately as shown. This is a correction and more precise determination of the finding reported last year. The mutant genes concerned are Curly, a dominant hair-modifying gene; anemia, a lethal resulting from a deficiency of red blood corpuscles; incisorless, complete absence of the important gnawing teeth; and brown, replacing black pigment in the hair.

The other positive finding is a demonstration of linkage between two genes, kinky and stub, which constitute a fourth (IV) linkage system for the rat. Kinky is a hair-modifying gene similar in its effects to Curly and Curly<sub>2</sub>, which also result in shortened curly hair, but kinky is a recessive in heredity, whereas the curly genes are dominants. Stub is a lethal when homozygous, which shortens the tail and produces other abnormalities particularly in the posterior half of the body, though it also results frequently in microphthalmia, especially in the left eye.

A cross between kinky and stub produces F<sub>1</sub> individuals normal in appear-

ance but carrying the two genes in the repulsion relation  $k/st$ . Such an individual when outcrossed to normal animals produces four classes of young, all alike and normal in appearance but different in fact, as can be demonstrated by mating them to F<sub>1</sub> animals which carry both genes. Such matings show the animals under test to be (1) carriers of  $k$  but not of  $st$ , (2) carriers of  $st$  but not of  $k$ , these two classes being non-crossovers; or (3) carriers of both  $k$  and  $st$ , or (4) carriers of neither, these two classes being crossovers. In 81 completed tests the indicated classes are 12 and 14 (crossovers) and 29 and 26 (non-crossovers). The totals are thus 26 crossovers to 55 non-crossovers, a crossover percentage of  $32 \pm 6.9$ . Further tests are being made to give this figure greater precision.

To summarize our present knowledge of linkage in the rat, we have four demonstrated linkage groups with map distances as follows:

I.	$\frac{l \quad c \quad r \quad p \quad w}{0 \quad 3.3 \quad 3.8 \quad 23.3 \quad 58.6}$
II.	$\frac{Cu \text{ } an \text{ } in \text{ } b}{0 \quad 4 \quad 8 \quad 45}$
III.	$\frac{hr \quad wo}{0 \quad 40.3}$
IV.	$\frac{k \quad st}{0 \quad 32}$

Other tests for linkage are in progress but with results as yet inconclusive.

PAUL S. CONGER, United States National Museum, Washington, District of Columbia.  
*Investigations and preparation for publication of results of studies on Diatomaceae.*  
(For previous reports see Year Books Nos. 18 to 41.)

Activities of the laboratory during the year consisted mainly of a continuation of studies of the distribution and ecology of Atlantic coast diatoms in particular, with some work on antarctic materials and other collections from smaller localized areas. The former is of special interest because of the great diversity of the coast line as a favorable region for abundant diatom growth, because of the economic aspects of the subject in relation to fisheries, and because of the prevalence of marine laboratories, where the related studies of marine biologists and oceanographers find increasing need for information regarding the diatoms. Many requests for such information were answered, including a number from members of the armed services regarding application to the war effort.

The comprehensive abstract bibliography of diatom literature, which has been in process of accumulation over many years, was greatly extended during this past year. This mine of information is still, however, much in arrears, because of lack of personnel to cover the vast amount of literature dealing with the many phases of diatoms and their importance. The value of this great amount of time-consuming work can only be appreciated when one considers the flexibility that will be afforded by its use.

Identifications of diatoms were again made for the Carnegie Institution Division of Plant Biology, in connection with studies on diatom pigments and their special photosynthesis. Many other identifications were also made for various workers in diverse fields of investigation.

A new and interesting application of diatoms came in the field of entomology. Selected diatom material of several types

was furnished to an entomologist for use as a "tagging" method, or marker, in dusting the bodies of aphids, in experiments to determine their course and rate of geographic distribution from a given center of growth. This is supplementary to a method using aniline dye powders for the same purpose, and has some advantages over the latter. The rate of dispersal is quite rapid and often follows a definite course. The obvious importance of these studies lies in their bearing not only on measures for the prevention of the spread of these pests, but also on the control of plant diseases transmitted by them.

Samples of diatomaceous materials of various composition were furnished to two laboratories for use in studies with the electron microscope, and this work led to the development in our own laboratory of experiments on a new method for the orientation of particular specimens of such material, which should be of considerable benefit in their study under the electron microscope. Such examinations have been made heretofore on random material chancing to fall in suitable position, rather than on definitely selected and oriented specimens. This possibility of orientation has evidently many advantages, but the method is unfortunately not applicable to other than diatomaceous materials.

Two months during the summer were again devoted to field research at the Chesapeake Biological Laboratory, during which time investigations, both qualitative and quantitative, were carried out on the production of marsh gas from diatomaceous lake-bottom sediments. Several new pieces of apparatus were devised for the work. These, the results obtained, and the general aspects of the whole problem

of marsh-gas formation from bottom sediments were summed up in an article prepared during the year, and now in the hands of the printer.

Some observations were also made while at the Chesapeake Laboratory on the rate of growth of diatoms on submerged surfaces, as a factor in the accumulation of

fouling materials on the bottoms of ships and other floating objects.

This varied information is being gathered and organized toward the preparation, already under way, of a general treatment of the whole subject of the diatoms and their importance.

ARTHUR T. HERTIG and JOHN ROCK, Boston Lying-in Hospital, Boston, and Free Hospital for Women, Brookline, Massachusetts. *Research in embryology, embryological pathology, and reproductive physiology.* (For previous reports see Year Books Nos. 36 to 41.)

The studies on these various aspects of human reproduction have had continued financial support through the Carnegie Institution of Washington's Department of Embryology. As in the past, additional funds from the William F. Milton Fund of Harvard University have helped to defray the technical and secretarial expenses involved in these joint researches.<sup>1</sup>

Since the last report, 2 additional normal, recently implanted human ova have been found in surgically removed uteri at the Free Hospital for Women. The patients from whom these uteri were removed constitute a special study group, the characteristics of which have recently been published by the authors (see bibliography). Eleven such patients have been operated upon in the past report year, bringing the total number to 72 for the past 5 years. From this group of patients there have been recovered 14 recently implanted ova, 9 of which have been normal and 5 abnormal. Thus the incidence of pregnancy in these rigidly selected patients continues to be approximately 20 per cent. This

figure constitutes, therefore, an index of human fertility within a group of known fertile patients who had recorded coital dates during the estimated period of ovulation preceding operation. These data, together with those pertaining to the time of ovulation, time of implantation, and location of the implanted ovum have recently been published by the authors.

Using these data on the time of ovulation together with those obtained in the recovery of two unfertilized tubal ova, the authors participated in a conference on "Biology of Fertility," held under the auspices of the National Committee on Maternal Health in New York City, in January 1943.

Using the series of 7 normal ova and 5 abnormal ova available up to the present report year, a paper was prepared on the development of the early human ovum with special reference to the trophoblast of the pre-villous stage. This paper was read before the Chicago Gynecological Society, in December 1942. A summary of this paper has appeared in the literature, and the entire paper will appear soon in the *American Journal of Obstetrics and Gynecology*.

The American Association of Anatomists did not hold its annual meeting in 1943 because of the war, but the abstracts of the papers thus canceled were published

<sup>1</sup> The Milton Fund largely supports Dr. Rock's researches on ovarian and tubal ova, whereas the Carnegie funds are used mainly in the search for early fertilized human ova. Inasmuch as the two authors collaborate in both these studies, credit is given to each Fund in reporting the results of the authors' past year's work.

in the *Anatomical Record*. The significant features of the  $7\frac{1}{2}$ -day ovum (Carnegie 8020) and the  $9\frac{1}{2}$ -day ovum (Carnegie 8004) whose recovery was recorded in Year Book No. 41 have thus been published during the past year.

The two recently implanted ova most lately acquired are estimated to be approximately 7 and 8 days of age, and were recovered on the 22d and 23d days of the menstrual cycle respectively. In some respects the younger one (Carnegie 8155) appears younger than the  $7\frac{1}{2}$ -day specimen (Carnegie 8020) recovered last year, and in others it appears more developed. It is smaller in its significant measurements and has a trophoblast that is less mature although the amniotic cavity is in a more advanced state of development. The ovum had probably been implanted approximately 24 to 36 hours at the time of its recovery. Thus the human ovum appears to implant when it is about 5 or 6 days of age; that is, on the 19th or 20th day of the standard menstrual cycle.

The trophoblastic shell of the ovum is very indifferently developed and is composed of the two main types of trophoblast, namely, syncytio- and cytotrophoblast. The former is actively engaged in invading the maternal tissue and engulfing portions thereof, to be subsequently digested and used as food for the growing ovum.

The embryonic or germ disk is of bilaminar form, consisting of the primitive ecto- and entoderm. The amniotic cavity has begun to develop as a cleft or space dorsal to the germ disk and is more or less continuous with the chorionic (or segmentation) cavity of the ovum. The amniogenic cells have not yet started to delaminate from the adjacent trophoblast.

Thus the specimen furnishes valuable data as to the time and manner of formation of the amniotic cavity.

The second specimen (Carnegie 8171), approximately 8 days of age, lies between the  $7\frac{1}{2}$ - and the  $9\frac{1}{2}$ -day specimens, but approaches the latter in its development. It is smaller than the  $9\frac{1}{2}$ -day stage, and its chief anatomical features are: (1) its relatively small size; (2) its relatively deep implantation; and (3) the early development of the syncytiotrophoblastic lacunae, elaborated for the reception of maternal blood. Little of the latter is present, as yet, in the spaces. This fact, together with its deep implantation, accounted for our inability to detect the ovum prior to fixation of the endometrium.

An additional significant feature is the developing amniotic cavity. It is quite similar to that of the 7-day specimen described above. Thus the two ova recently acquired elucidate a critical phase in the development of a structure, the amnion, whose early stages in man have heretofore been little understood.

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T. H. MORGAN, HELEN REDFIELD, and L. V. MORGAN, California Institute of Technology, Pasadena, California. *Maintenance of a *Drosophila stock center, in connection with investigations on the constitution of the germinal material in relation to heredity.* (For previous reports see Year Books Nos. 15 to 41.)*

An inventory of the stocks of *Drosophila melanogaster* at the California Institute of Technology is as follows:

*Mutants.* Chromosome (1), 183; (2), 223; (3), 179; (4), 21; multi-chromosomal, 11. Attached-X, 3. Deficiencies: X, 14; (2), 29; (3), 2; (4), 1. Duplications, 18. Inversions: X, 32; (2), 5; (3), 11. Translocations: (1;2), 13; (1;3), 16; (1;4), 11; (Y;2), 2; (Y;3), 1; (2;3), 25; (2;4), 6; (3;4), 10. Haplo-4, Triplo-4, and 3N, 5. Total mutants, 821.

*Wild stocks.* Canton-S; Lausanne-S; Oregon-R-c; Swedish-c; Urbana-S. These stocks are available for research students.

The work of Helen Redfield for the past year falls under two heads: first, the study in *Drosophila melanogaster* of mosaic eyes in intersex offspring of triploids, and, second, the completion of the studies in the same species of the effects of the presence of inversions on crossing over in other chromosomes. For summaries of the previous studies of Schultz and Redfield on this second topic see Carnegie Institution Year Books Nos. 29 to 34 (1930-1935).

It has long been known that the eyes of eosin intersexes of all sex grades show the lighter color of eosin males rather than the somewhat darker color of eosin females. A heritable mosaic eye appeared in the intersex progeny of free-X eosin triploids; a definite proportion of the light eyes of these intersexes (25 per cent) show patches of a darker color like that of the 2N eosin females. A dark patch ordinarily includes about a quarter of the eye area; it may be smaller than this or larger, in extreme cases being so large as to include an entire eye. One eye, both eyes, or neither eye of an individual inter-

sex may be affected. All eosin triploids of this strain gave mosaic intersexes.

An unrelated strain of triploids with two attached X chromosomes and a third free X was then crossed to males of the eosin stock. The first eosin attached-X triploids obtained did not give mosaic intersexes, but further backcrossing to eosin produced triploids which did. The results were then substantially as they had been in the free-X strain. This would suggest that something in the eosin stock, not the eosin gene itself, was responsible.

Free-X eosin triploids were then crossed to apricot. In this allele of eosin the color differences are not so great as for eosin, and the color relations of the sex types are reversed; that is, apricot males are darker than apricot females, and apricot intersexes show the slightly darker color of the 2N apricot males. When apricot triploids were obtained they gave mosaic intersexes as did the eosin triploids; but the patches were lighter than the surrounding area, instead of darker, as in the eosin mosaic eyes. Thus the mosaic patches in either case take on the color of the female eye.

It was thought, since not all intersex offspring showed the mosaicism, that the latter might be immediately correlated with the presence of the Y chromosome; for intersexes (2X3A) may or may not contain a Y. Accordingly a stock of yellow, Hairy wing, eosin was derived and was crossed to eosin triploids. The Hairy wing intersex offspring probably contain no Y, but the non-Hairy wing intersexes have received their father's Y. The classification of Hairy wing is not satisfactory in these intersexes (even the appearance of the extra occipital bristles is irregular), but it is definite enough to show that

both Hairy wing intersexes and non-Hairy wing intersexes may be mosaics. Hence the mosaicism is not a direct Y effect unless Y chromosomes are introduced from the mother. It may in any case depend indirectly on the presence in the triploid mother of one or more Y chromosomes. It is possible that an additional effect of another type is involved—autosomal chromosome elimination, for example, giving 2X2A patches, or somatic crossing over. It is not known whether the mosaicism appears only with sex-linked sex-limited characters, or is found also with other sex-linked mutants (as singled), and with autosomal mutants of various types. All these matters can be tested.

This year's studies on inversion effects on crossing over were undertaken to confirm the peculiar results shown by the

the Curly inversions in the second chromosome and of the ClB inversion in the first chromosome, either together or alone, increased crossing over for most regions of the third chromosome, but not so markedly as did ClB and Payne for (2); in certain regions of (3), unlike (2), the effect was apparently a decrease rather than an increase. We believed that these differences were correlated with differences in distribution of heterochromatin in the two large autosomes. It was thought desirable to test in further detail the right limb of (3). Two types of mother were used: *ri Sb H/p<sup>p</sup>* to test the central region of this chromosome, and *e<sup>4</sup> ro/bv* to test the extreme right end. XXY mothers, which occur with appreciable frequency in ClB strains, were excluded. The summarized results are shown in the accompanying table.

Inversions	N	Crossover values			Per cent increase		
Mothers <i>ri Sb H/p<sup>p</sup></i> :		<i>ri-p<sup>p</sup></i>	<i>p<sup>p</sup>-Sb</i>	<i>Sb-H</i>	<i>ri-p<sup>p</sup></i>	<i>p<sup>p</sup>-Sb</i>	<i>Sb-H</i>
Control.....	2096	0.76	7.1	11.2	.....	.....	.....
ClB.....	2245	1.07	9.5	11.7	40.8	33.8	4.5
Cy.....	3103	0.52	12.2	14.5	-31.6	71.8	29.5
ClB, Cy.....	2698	1.08	19.0	15.6	42.1	168.0	39.3
Mothers <i>e<sup>4</sup> ro/bv</i> :		<i>e<sup>4</sup>-ro</i>	<i>ro-bv</i>		<i>e<sup>4</sup>-ro</i>	<i>ro-bv</i>	
Control.....	2551	19.4	14.9		.....	.....	
ClB.....	2216	23.2	16.3		19.6	9.4	
Cy.....	2491	21.0	14.3		8.2	-4.0	
ClB, Cy.....	2564	24.2	18.1		24.8	21.5	

third chromosome as compared with the second, as previously found by Schultz and Redfield. It was desired also to extend the analysis to the first chromosome, for, excepting the work of Steinberg (1936, 1937), there are no extensive data on the effects of inversions in (2) and (3) on crossing over in (1), and Steinberg's crosses do not include the critical spindle-fiber region.

It had been found that the presence of

The percentage increases found in the table are obtained by dividing the actual increases by the respective control crossover values. It is clear that the first-chromosome inversion produces an increase in crossing over throughout this right limb of (3). The second-chromosome inversions also produce increases with the apparent exception of the *ri-p<sup>p</sup>* and *ro-bv* regions, in which there are decreases; these decreases are in themselves not of statistical

significance, but are like those found in the earlier crosses. The combination of inversions of (1) and (2) produces marked increases in all regions, particularly in the middle of this right limb. The first-chromosome CLB inversion is thus more effective in increasing crossing over at the center and at the extreme right end of (3) than the second-chromosome Cy inversions, but for the intermediate regions Cy has more effect than CLB. The results are in essential agreement with the results previously obtained for (3).

Extensive tests were made of crossing over in the first chromosome, using the second-chromosome Cy inversions and the third-chromosome Payne inversions. The mothers were of the composition  $y^2 cv v f/ec car bb$ . The data are not yet all tabulated, but the results so far may be given briefly. The increases in crossing over divided by the control values, i.e. the percentage increases, for the various regions are as follows: for  $y^2-ec$ : Cy=85.2; Payne=68.7; Cy, Payne=198.0. For  $ec-cv$ : Cy=106.0; Payne=47.8; Cy, Payne=176.4. For  $cv-v$ : Cy=51.5; Payne=29.0; Cy, Payne=69.6. For  $v-f$ : Cy=27.0; Payne=42.9; Cy, Payne=77.2. For  $f-car$ : Cy=8.3; Payne=69.4; Cy, Payne=120.8. For  $car-bb$ : Cy=2.2; Payne=17.8; Cy, Payne=132.8. Further analysis of the results of these crossover studies and the discussion of the theoretical implications are better left for the detailed presentation.

L. V. Morgan reports observations on two characters heretofore undescribed. A rough eye character called sparkling (*spa*) in *Drosophila melanogaster* is associated with some alteration in chromosome (4). Homozygous *spa* flies carrying a fragment of chromosome (4) derived from translocation T(2;4)b showed exaggerated sparkling, indicating that the locus in (4) which is responsible for *spa* is not within the limits of the duplicating fragment.

The fragment extends from the centromere of chromosome (4) to the distal range of the bands of section 102C of the salivary chromosome. In preparations of salivary glands, chromosome (4) when it carries *spa* shows a pale area proximal to the dark band 102D1. The two lines of evidence combined place the locus of *spa* in the distal ranges of the section 102C.

Sparkling is an allelomorph of Cataract (Belgovsky), which is a dominant character manifested by roughness of the eye, more particularly of the posterior edge. When Cataract is heterozygous for *spa*, the anterior part of the eye is rougher than in Cataract over wild type.

Sparkling shows characteristics of a variegation. It is affected by the proportion of heterochromatin to euchromatin present in the nucleus. For example, in homozygous *spa* flies, sparkling is regularly seen in XX females, but not in XXY females, or in males (XY). It is exaggerated in XO males. Sparkling is sensitive also to other proportions of heterochromatin and euchromatin. It not infrequently shows exceptional grades of manifestation due presumably to modifiers. It is of a higher grade when flies are raised at low temperatures.

Regular smooth-eyed homozygous *spa* males were X-rayed, and mated to homozygous *spa* females. Among the offspring a number of variants of *spa* were found and have produced lines which have not yet been cytologically studied in salivary chromosomes.

Among these lines there are 15 to 20, each derived from a smooth-eyed daughter of a treated male, in which females as well as males are smooth-eyed when homozygous for the treated chromosome or heterozygous for *spa*. In a few of the lines flies homozygous for the treated chromosome are more or less inviable. Those lines are balanced with a fourth chromo-



some carrying  $ci^D$  (cubitus-interruptus dominant) and the normal allelomorph of  $spa$ , showing that it is chromosome (4) that has been altered by the X-ray treatment.

Thirty of the treated males mated to sparkling females each produced a high-grade rough-eyed son heterozygous for the treated chromosome and for  $spa$ . Most of them were sterile, but three gave rise to lines which show that in them the excessively rough character is recessive to the wild-type allelomorph of  $spa$  (in a  $ci^D$  chromosome). In one of the lines the altered chromosome is lethal when homozygous.

The translocation  $T(2;4)b$  was used to determine more closely than heretofore the loci of shaven-naked ( $sv^n$ ) and of recessive eyeless ( $ey^*$ ). Both were found to be distal to the break in  $T(2;4)b$ , i.e., distal to the proximal bands of section 102C of the salivary chromosome.

Diploid intersexes have been found in

*Drosophila melanogaster* due to a recessive gene ( $ix$ ) located at  $60.5 \pm$  in chromosome (2). Flies carrying two X's which are heterozygous for  $ix$  are entirely female in appearance and are fertile females; 2X individuals homozygous for  $ix$  are sterile intersexes. They have no sex combs, but show in varying degrees both male and female characteristics in regard to shape and pigmentation of the abdomen and the presence of male and female genitalia and gonads.

Flies carrying one X are fertile whether heterozygous or homozygous for  $ix$ . The two genotypes have been so far indistinguishable in appearance, and both are fertile as males. Intersexes are intermediate in size between females and males. The weights of 31 etherized females (heterozygous for  $ix$ ), 31 intersexes, and 31 males (heterozygous or homozygous for  $ix$ ) of a sample from one culture were respectively 0.037, 0.034, and 0.024 grams.

G. OSCAR RUSSELL, Washington, District of Columbia. *Researches in the physiological cause of voice quality differences.* (For previous reports see Year Books Nos. 28-33, 35, 37, 38.)

Equipment was conditioned and reconstructed for a final check on the validity of our previous analysis and classification of voice disorders apparently caused by deafness. For that purpose, we returned to Columbus, Ohio, where the first check had been made, and carried through a new group of entering children in the Ohio State School for the Deaf. All these are so young that they represent those usually designated as congenitally deaf, since their hearing was impaired before normal speech and voice habits had been established, and it is difficult to determine with any degree of accuracy just when the impairment occurred. Where they are all below age six, and the deafness is profound, the

experiments show that the voice quality and manifestations are never normal. That is due undoubtedly to two factors: first, the transient nature, and difficulty of permanent fixation, of any habits acquired in that period; and, second, the consequent lack of acoustic engrams, or auditory control patterns. We now know that over 40 per cent of the meaning of speech is conveyed by intonation or voice differentiations rather than by the words themselves. The experiments show definitely, therefore, that it is this voice factor which accounts for a large part of the difficulty one has in understanding the speech of the congenitally deaf. If means of training a substitution for the acoustic engrams

could be devised, a profound improvement might well be expected.

Three major studies bearing on this problem have been published since the last report, all being monographs of the Utah State Research Laboratories: *The language of the deaf*; *The language of the blind, a comparative study*; and *The organization for a training program*.

The following have been completed: the pathological classification, on diseases affect-

ing the voice; the phonetic classification; the classification of physiological and congenital anomalies affecting voice; the psychiatric; the neurological and cortical lesion effects; the psychological in its abnormal manifestations; and the mnemonic. They are being published in the form of classification tables, analysis articles, and definitions, in a *Cyclopedic medical dictionary of speech, voice, and hearing disorder terms*, now in press.



## DIVISION OF HISTORICAL RESEARCH

*Cambridge, Massachusetts*

A. V. KIDDER, *Chairman*

During the past year the Division has undertaken no archaeological exploration or excavation, nor is it probable that activities of this sort can be resumed for some years to come. Not only has field work been suspended, but many members of the staff—archaeologists, ethnologists, historians—are now, or soon will be, in the armed forces or engaged in other activities connected with the war. Hence no fresh archaeological data are coming in. Moreover, the men in service are of course unable to complete reports on investiga-

tions in progress at the outbreak of hostilities. Among them are several of particular importance: H. E. D. Pollock's architectural survey of Yucatan; G. W. Brainerd's and J. M. Longyear's studies of the pottery of Yucatan and Copan; G. Strömsvik's excavations at Copan; and A. L. and R. E. Smith's work at Uaxactun. The research of A. M. Halpern on the Maya languages has also been interrupted, as have the studies by R. S. Chamberlain on the history of the conquest of Yucatan.

### ACTIVITIES 1942-1943

During the period under review several members of the staff and associates have entered war service. H. E. D. Pollock is an officer of the Army Air Corps on duty in North Africa. K. Ruppert is overseas with the American Field Service. R. E. Smith is working with the United States military attaché in Guatemala. G. Strömsvik is in the Norwegian Navy; G. W. Brainerd and E. W. Andrews are in that of the United States. R. S. Chamberlain is Senior Cultural Assistant in the United States Embassy in Guatemala. A. M. Halpern is giving instruction in Japanese at the University of Chicago. Others have been engaged in the writing of reports: S. G. Morley on the hieroglyphic inscriptions, A. L. Smith on the excavations at Uaxactun, J. E. S. Thompson on those at El Baul, E. M. Shook and A. V. Kidder on those at Kaminaljuyu, Anna O. Shepard on plumbate pottery, Tatiana Proskouriakoff on Maya architecture and sculpture, E. H. Morris on excavations in Colorado, F. V. Scholes and R. L. Roys on

various aspects of Yucatecan history. S. L. Bradshaw has continued preparation for the press of the exhaustive study of Maya grammar left unfinished at the death of M. J. Andrade.

Before entering service, Mr. Strömsvik returned to Copan to make arrangements for storage of Institution equipment and for supervision of the ruins and museum by the Government of Honduras. Mr. Shook, who is temporarily remaining in Guatemala, has had opportunity to carry out certain minor explorations. He has also studied local museum and private collections and has investigated several finds of archaeological material made in the course of road and airfield construction and by private individuals. Most notable of the latter was a cache of plumbate vessels and a gold plaque unearthed near Quezaltenango by Sr. Vitalino Robles, who most generously made these very important specimens available for study.

F. B. Richardson was obliged, for reasons of health, to postpone further work

on the problem of the deeply buried human footprints near Managua, Nicaragua. He is now in South America, making observations on monumental stone sculpture for comparison with that of the Maya area. S. H. Boggs completed the photographing of several large collections of pottery in Salvador and has also been preparing a final report on the excavations at Campaña San Andres, which were financed and carried out by Mr. John Dimick under the auspices of Carnegie Institution.

More detailed reports on certain activities follow.

#### HIEROGLYPHIC RESEARCH

S. G. MORLEY

Dr. Morley spent the summer of 1942 in Santa Fe, New Mexico, with offices at the Laboratory of Anthropology, where on June 1 he began the writing of a popular book on the Maya civilization, *The ancient Maya*. He returned to Merida, Yucatan, September 1 and has since been devoting his time to the completion of the book, which he finished early in June 1943. During the fall, winter, and spring he made a number of trips to Uxmal, and early in May visited the newly founded Museo Arqueológico, Etnográfico e Histórico del Estado de Campeche, at Campeche, a splendid local institution.

Work on the hieroglyphic dictionary has gone forward. All Initial Series introducing glyphs at 39 sites (Copan and the 38 sites covered in Dr. Morley's study *The inscriptions of Peten*) have been drawn to scale, each on a separate card. Work has been commenced on another section of the dictionary, that presenting all known examples of Glyph C of the Supplementary Series.

In cooperation with the Instituto Nacional de Antropología e Historia of the

Secretaría de Educación Pública, the Campeche Museum has been excavating the ruins of Etzna, an extremely important site in central Campeche which has close affiliations not only with the Old Empire but also with the Puuc Period of the New Empire. Three new Initial Series were discovered, as follows: Stela 18, 9.12.0.0.0 10 Ahau 8 Yaxkin; Stela 19, 9.13.0.0.0 8 Ahau 8 Uo (?); and a third, a fragmentary one, inscribed on the risers of the hieroglyphic stairway leading to the principal temple.

Mr. Alberto Ruz Lhuillier, of the Instituto Nacional de Antropología e Historia, who was in charge of the excavation at Etzna assisted by Mr. Raul Pavon Abreu, Director of the Campeche Museum, spent a week studying the Institution's ceramic sherd collections in Merida toward the end of May.

#### CERAMIC TECHNOLOGY

ANNA O. SHEPARD

The study of plumbate ware, outlined in Year Book No. 41, has been continued through the current year. In the summer of 1942 collections in Mexico, Guatemala, and Salvador were examined, and with the assistance of Miss Janice Snow in tabulating and sketching, a complete descriptive and photographic record was made of plumbate vessels in the national museums of the countries visited and in ten large private collections. The most generous cooperation was received from museum officials and owners of collections. The file on plumbate ware has thus been extended by 344 vessels and now furnishes an adequate basis for defining plumbate style and workmanship, a task necessary in order to determine the relationships of this important ware.

While in Guatemala Miss Shepard visited the site of Tajumulco in company

with Mr. Shook, and short reconnaissance trips were made to several near-by sites. The frequency of occurrence of plumbate in this area, as well as indications of the population which the region supported, are of particular interest because of the large collection of plumbate vessels excavated from Tajumulco under the auspices of the Museum of New Mexico.

Several weeks in Guatemala City were spent in microscopic examination of sherds from the 1942 excavations of Mr. Thompson at El Baul and Mr. Shook at Kaminaljuyu. Subsequently plumbate ware from both sites and other wares from El Baul, particularly that called Tiquisate, which is associated with plumbate and bears some resemblance to it in oxidized surface colors, were thin-sectioned in the laboratory and analyzed petrographically. When the paste and slip of plumbate from El Baul and Kaminaljuyu were compared with those of typical plumbate, Miss Shepard noted minor differences, which may be significant in view of the distinct vessel shapes characteristic of these two sites.

The remainder of the year has been devoted to the preparation of the plumbate report.

#### SOUTHWESTERN ARCHAEOLOGY

E. H. MORRIS

The entire year ending June 30, 1943 was spent by Mr. Morris in office work. A minor but time-consuming part of the latter consisted of the revision of archaeological manuscripts submitted to him for criticism.

Early in September, Robert F. Burgh, who had been a collaborator in the Southwest Project for several years, joined the armed forces. His many drawings for the report on Basket Maker sites near Durango, Colorado, excavated during 1938,

1939, and 1940, were in various stages of completion at the time of his departure. By March, with the assistance of Miss Jean Zeigler, these had been brought to what is believed to be the finished stage. Captions were prepared to document the more complicated of the drawings, and considerable progress was made in the study and photographing of specimens from the Durango sites.

In order to utilize the technical skill of Miss Zeigler, after the Durango drawings were finished, the analysis and graphic depiction of the weaves of Basket Maker sandals was begun. For this study a large body of material is in hand—some 300 sandals from dry caves in northeastern Arizona excavated by Carnegie Institution under the direction of Mr. Morris in 1931. In the fabrication of Basket Maker sandals the Anasazi reached their highest attainment in textile art. Although the sandals are of a number of varieties, in the finer types customarily the upper side bears zones of delicate patterns in color and the under side is decorated with patterns in relief, usually more involved than the colored ones on the opposite surface. These hand-woven relief patterns were produced by manipulations of the weft strands so devious that only by most careful dissection and the drawing of each stitch as it is unraveled can the construction of the fabric be determined. Only one Basket Maker sandal has hitherto been thoroughly reported upon, that described by A. V. Kidder in the *American Anthropologist*, n. s., vol. 28, pp. 618–632 (1926). In view of the several styles evident among the sandals and of the wide variation in layout and visual effect within the styles, a complete study of the highly complicated technique evolved and practiced by the Anasazi has for years been called for. Such a study will be a long undertaking, but it is the intention of Mr. Morris to continue with it

until the results can be presented in a publication comparable in thoroughness and detail with *Anasazi basketry*, which came from the press in 1941.

#### SOCIAL ANTHROPOLOGY

ROBERT REDFIELD AND ASSOCIATES

Dr. Tax spent most of the year in Mexico. From July through November he taught at the Escuela Nacional de Antropología; December and January he spent with nine students in the Tzotzil community of Zinacantan, Chiapas, instructing them in techniques of ethnographic field work. February he also devoted to this work, assisting the students in preparing a report on the work of the expedition. The next months, to the middle of June, were devoted chiefly to making last revisions of his manuscript on *The economy of the Indians of Panajachel, Guatemala*.

While in Mexico, Dr. Tax began, with the cooperation of the Escuela Nacional de Antropología and the collaboration of its cartographer, Sta. Rita Lopez de Llergo, a large-scale language-density map of the Maya area. This map makes use of data from the original schedules of the 1940 Census of Mexico, furnished through the courtesy of the Department of Statistics of the Mexican Government, to spot the population, classified by language reported spoken, as accurately as possible. When the Mexican part is completed, it is hoped to extend the localization on the map to Guatemala, British Honduras, and the Republic of Honduras. As projected and begun, this map will be an improvement not only over previous linguistic maps of the area, but over population-density maps as well, since the population is spotted by the smallest local units. Sta. Lopez de Llergo has adapted to cartographic purposes a decimal system of indicating the numbers of people.

Dr. Tax, while in Mexico, was in contact with the group of linguistic missionaries of the Summer Institute of Linguistics. This organization has trained linguists stationed in many Indian communities in the country, including some in outlying Maya communities on which there is almost no ethnological information. Finding them eager to be of assistance, Dr. Tax took time to instruct many of them in methods of obtaining reliable ethnographic data.

The expedition to Zinacantan, although primarily a training enterprise for students of the Mexican Institute of Anthropology, furnished a considerable body of data on this hitherto unknown community. The whole Tzotzil group has been almost untouched by scientific research. In conjunction with the results of Sr. Villa's work among the Tzeltal, the results of the expedition give us a good start in understanding the ethnology and sociology of the Maya groups in Chiapas. The report of the expedition is still incomplete, but will probably be published in Mexico within a year. As a further result of this expedition and of Dr. Tax's teaching program in Mexico, a new research project, in which three of the students will return to the same region of Chiapas for six months each to work on problems of social anthropological interest, is under serious consideration. As planned, it will be financed cooperatively by the Instituto Nacional de Antropología e Historia, the State of Chiapas, and the University of Chicago, and will get under way in the autumn of 1943.

Sr. Rosales remained in Chicago until January, when he returned to Guatemala to continue the writing of his report on San Pedro la Laguna. Plans for publication of the first volume, on the technology, in Guatemala are going forward while he is working on the chapters on the economy.

Sr. Alfonso Villa R. spent about ten

months studying Tzeltal communities (Dzajalchen, Yaxanal, and Tzuib). His wife accompanied him, and a field residence and "branch office" of the Institution was built in Dzajalchen. In spite of difficulties—the absence of Indian men for periods of work on fincas, poor food, sickness, and the hostility of the Indians toward whites—Sr. Villa recorded excellent and abundant material. The institutions of these Indians include exogamous patrilinear groups, cross-cousin marriage, a dual division with ritual functions, and a remarkable form of witchcraft in which the sorcerer (in many cases) causes illness as a punishment for a sin committed by the sick person or a relative, and in which cure follows confession and lustrative whipping of the sinner, after divination, or diagnosis, by "pulse-takers." Villa will devote the summer and autumn to preparation of a report, and to giving a course in ethnological field method in the Escuela Nacional. His manuscript on *The Maya of east central Quintana Roo* has been submitted for publication.

During the year plans to undertake a study of nutrition in Guatemala, to begin this summer, matured. Dr. Tax will direct the project, and the field work will be done by Srs. Antonio Goubaud Carrera and Juan Rosales. Sr. Goubaud, like Sr. Rosales, is a Guatemalan; this will be his first official connection with the Institution's program, although relations between him and members of the staff have been close since 1934 and he has spent the past years at the University of Chicago working partly under Dr. Redfield. In 1942 he participated in a nutrition study, jointly sponsored by the Office of Indian Affairs and the University of Chicago, in New Mexico. Plans call for study of the diet of both Indian and Ladino communities in every region of Guatemala.

During the summer of 1942 Dr. Gillin,

under a cooperative arrangement with Duke University, engaged in a preliminary study of San Luis Jilotepeque, a Pokoman community of eastern Guatemala. Mr. Melvin Tumin then spent about nine months in the same community working especially on problems of acculturation and the relations of Indians and Ladinos. Supported by the Social Science Research Council, with collaboration of the Institution, he did his work under the direction of Drs. Redfield, Gillin, and Tax.

### HISTORY OF THE MAYA AREA

F. V. SCHOLES, R. L. ROYS

During the past year Mr. Scholes has devoted a large part of his time to preparation of chapters for the volume on the history of the cacicazgo of Acalan-Tixchel to the early seventeenth century. In the spring of 1943 Mr. Roys, who is collaborating in this work, spent four weeks in Albuquerque with Mr. Scholes, during which time various problems connected with preparation of the manuscript were ironed out. The volume will be ready for the press not later than the autumn of 1943.

From time to time during the past year documentary materials relating to other topics have been studied and extracted. Papers based on these sources will eventually be prepared for publication, but certain points should be noted at this time because of their obvious interest for specialists in Maya studies.

One series of documents contains data concerning native ruling families in the Chancénote area, or cacicazgo of Tazees. We learn that a certain Ahau Chan was lord of eight towns in this region prior to the conquest and for some years after the arrival of the Spaniards. He was succeeded by his son, Don Juan Chan, and the latter, in turn, by Don Juan Chan the Younger, who was cacique and governor of Chance-



note for about thirty years during the latter part of the sixteenth century and the early years of the seventeenth. Chan the Younger married Doña Isabel Tzeh, daughter of Don Fernando Tzeh, who was natural lord of other towns in the Chancénote area and "descended from the ancient lords of Mayapan." Thus we have record of other Maya families which, like the Xiu, the Pech, and the ruling house of Acalan-Tixchel, were able to retain a measure of power after the conquest, and we learn of another line of rulers which traced its ancestry back to chieftains resident in Mayapan prior to the disruption of the confederacy and the abandonment of the city. The name Tzeh suggests that the cacicazgo of Tazees derived its name from this family.

During his term of office as governor of Chancénote, Don Juan Chan the Younger received various commissions from the governors of Yucatan and performed numerous services which contributed to the advancement of the missionary program. He took an active part in the resettlement of fugitive and heathen Indians in the eastern and coastal areas of the province, and on one occasion collaborated with Dr. Pedro Sanchez de Aguilar, *cura* of Chancénote, in the extirpation of idolatry. The Chan papers are supplemented by the *probanzas*, or proofs of services, of Sanchez de Aguilar, which also mention the idolatry incident. Although the two sets of papers do not contain much detail concerning this episode, it is recorded in one place that during the affair, which occurred about 1604, Sanchez de Aguilar destroyed more than twenty idols and "three books of heathenism and idolatry written on the bark of trees, with the figures of devils which they worshipped." So it appears that Sanchez de Aguilar must share with Landa and others responsibility for the destruction of many of the ancient hieroglyphic writings of the

Maya. In later years Sanchez de Aguilar wrote the well known treatise *Informe contra idolorum cultores del obispado de Yucatán*, thus emulating in another respect the example of Bishop Landa, author of the famous *Relación de las cosas de Yucatán*.

Another series of documents describes the serious disorders which occurred in the pueblo of Sahcabchen, southeast of Champoton, and in adjacent areas in the 1660's and 1670's. Although the major causes of unrest were abuses committed by provincial authorities and raids by English ships along the Gulf coast, we are also told that one source of trouble was the activity of certain Indians, including a native priest, who went about preaching that according to prophecies the time had come for the Indians to abandon their settlements and take refuge in the bush and forest regions of the interior. Interpretation of these data will require considerable study, for the information is by no means explicit. The testimony may refer to one of the year prophecies, but it seems more likely that a katun prophecy, such as we find described in the books of Chilam Balam, is indicated. These documents and the idolatry episode mentioned in the preceding paragraph serve to illustrate the survival of Maya religion and the influence of the native priesthood.

From the Sahcabchen papers and the documents which comprise part of the source for the Acalan-Tixchel volume we are able to glean interesting data concerning settlements of fugitive and apostate Indians in the central and southern part of the peninsula in the seventeenth century. Some of these settlements were located in the Matamoros-Cilvituk-Chan Laguna region, and chapter 9 of the Acalan-Tixchel volume will deal with missionary enterprise in this area from 1604 to 1615.

Perhaps most interesting, in view of the

growing interest in the archaeology of southern and southwestern Campeche, are references to the site called Bolonpeten. Maler was the first person in modern times to mention this place. In his *Explorations in the Department of Peten, Guatemala, and adjacent regions (Memoirs of the Peabody Museum, vol. 4, p. 146)*, he described his journey through central Yucatan, and in connection with his account of the Cilvituk ruins he wrote:

Incidentally, . . . about the middle of the nineteenth century, many free Maya families still dwelt in the precincts of Chanlaguna and Silbituk. Their principal settlement is said to have been at Bolonpeten, some two leagues west of Chanlaguna. This is a swampy region containing islands, hence the name, "Nine Islands." Many pottery sherds are said still to lie around there, but the people themselves have totally disappeared.

Andrews, in his *Archaeology of southwestern Campeche* (Carnegie Institution of Washington Publication 546, p. 37), gives additional information concerning this swampy area. He states that it is called Isla Pac, which "means in Spanish-Maya 'island with walls,' or 'island with ruins.'" Continuing the discussion, he notes that the ruins at Isla Cilvituk and Las Ruinas north of Isla Pac are "among the last products of indigenous architecture," and states the belief that the ruins in Isla Pac, or Bolonpeten, if found, "might well bridge the gap between our knowledge of late pre-Spanish archaeology and early historical information. Or they might prove that the two overlap."

From the documentary sources we learn certain facts concerning this place. A document of 1605 refers to it as an old site (*asiento antiguo*). The exact meaning of this phrase is not clear, but the context implies that the place was not occupied in 1605. The Sahcabchen papers describe

it as a place "surrounded by nine small islands (*islotas*)," from which it was possible to go by canoe to Popola, located on or near the lower course of the Mamantel River. It was inhabited at this time (1670) and its cacique was one of the leaders of the malcontent Indians of the interior. We have no positive record that the place was occupied at the time of the conquest, but there is some evidence that when the Spaniards arrived some of the Cehache settlements may have extended as far north as the Cilvituk region. Data on this point will be presented in the Acalan-Tixchel volume.

During the year Mr. Scholes and Miss Adams published a paper on "Books in New Mexico, 1598-1680," a contribution to the intellectual history of colonial Spanish America. They have also made progress on a volume entitled *Don Juan Domínguez de Mendoza, soldier and frontiersman of the Southwest*, to be published in the Coronado Historical Series sponsored by the University of New Mexico.

Dr. Chamberlain, who is on leave of absence, continued to serve as Senior Cultural Assistant of the United States Embassy in Guatemala City.

## UNITED STATES HISTORY

L. F. STOCK, J. J. MENG

Dr. Stock's sixth volume of *Proceedings and debates of the British Parliaments respecting North America* in its final editing has not progressed beyond 1758. But if war restrictions, especially those found necessary by the Library of Congress, have thus retarded the editorial progress of the work, the process of assembling and preparing for the printer the selected text for the volume has gone steadily forward, so that its publication should not be unduly delayed. It has also been possible, because of this editorial interruption, to examine

collections outside Washington for pertinent materials. Especially profitable was a visit to the William L. Clements Library, Ann Arbor, Michigan, whose rich collections yielded much for both text and annotation. For the period beyond that covered by the fifth volume the materials become more plentiful for each succeeding year. This is especially true of reports of parliamentary debates. This abundant mass may make necessary in future volumes some departure from the plan of inclusion and exclusion which has heretofore been followed. Whatever decision may be reached will, it is hoped, result in no sacrifice of the utility of the series, which reviewers without exception have generously acknowledged.

During the year Dr. Stock has continued to put in order the old files of the Division, which have considerable value to the historian and biographer. He has answered many queries of historical nature sent to the Institution, and he has given assistance in many ways to several investigators. He again served as chairman of the Committee on Publications of the American Catholic Historical Association, and on the Executive Council of that organization as one of its past presidents. He lectured twice before the Charles Carroll Forum on "The diplomatic relations between the United States and the Vatican"—in Washington April 11, and in Chicago April 18, 1943.

The general dislocation of the Institution's activities caused by the war has been reflected in the progress toward publication of the *Guide to materials for American history in the libraries and archives of Paris*. Volume II, devoted to the French Foreign Office archives, was not published as anticipated during 1942. It is hoped that it will appear before the end of 1943. All that prevents its appearance are the technical difficulties of printing and binding a very large volume under wartime con-

ditions. Volume III, comprising notes on the archives and libraries of the War Office, the Ministry of Marine, the Comité de l'Artillerie, the Comité Technique du Génie, and the Service Hydrographique, is complete in manuscript form. Publication must wait upon the prior demands of other projects considered of more immediate importance.

Although publication of this work has been delayed, research for the remaining volumes is continuing. Dr. Waldo G. Leland, the general editor, is supervising the work of Dr. John J. Meng on the materials which have not yet been collated and prepared for publication. The manuscript of volume IV, which will list and describe the various Actes du Pouvoir Souverain relating to America, as well as materials from the Archives Nationales and a number of minor depositories, is virtually complete. The plan of treatment for volume V, the last, and one of the most important volumes of the series, has been decided upon, and preparation of the manuscript will be well under way before the end of the year. That volume will deal with the centrally important Archives des Colonies.

## HISTORY OF SCIENCE

GEORGE SARTON

*Introduction to the history of science.* In the previous report the completion of the first half of volume III was announced. The second half (dealing with the second half of the fourteenth century) is now almost completed. Twenty-five chapters out of twenty-eight are written, and the manuscript of volume III will probably be ready for submission to the Carnegie Institution in September.

*Editing of Isis.* Volume 34 is in course of publication. It is now printed in two columns for the sake of economy. It has

not yet been possible to renew the publication of *Osiris*, for which much material has accumulated.

The proofreading and editing of *Isis* are taken care of by Dr. Pogo, who also conducts many minor investigations entailed by the editing and by the *Introduction*.

#### PUBLICATIONS

MARGARET W. HARRISON

In December 1942 the Institution published *Archaeological researches in the northern Great Basin* (Publication 538), by L. S. Cressman, of the University of Oregon, and others. Specialists in anthropology, archaeology, paleontology, geology, and climatology cooperated in this study of the history of early man in south-central Oregon.

*Archaeological reconnaissance in Campeche, Quintana Roo, and Peten* (Publication 543) came from press in April 1943. A detailed account of the work of four expeditions—1932, 1933, 1934, and 1938—the book is illustrated by 126 line-cut drawings, 60 gravure plates, and 15 maps. To facilitate cross reference, the subject matter is arranged by structure under each site. Karl Ruppert wrote the introduction, summary, and description of the ruins; the late John H. Denison, Jr. recorded the epigraphy, which Mrs. Harrison subsequently reorganized under schematized headings for each stela in numerical order at every site. A number of Mr. Denison's photographs of the monuments and rubbings were not published, but they are available upon request to the Peabody Museum of Harvard University.

In process of being printed is Ralph L. Roys' *The Indian background of colonial Yucatan*. Part I describes the country, the people, and their way of life as the Span-

iards found them. Mr. Roys has adapted much of the material from his manuscript on the Xiu Chronicle (now deposited in Peabody Museum), and presents it as part II, a discussion of the cacique system in Yucatan. This volume is the first in a proposed series of historical studies on the Maya area. The second, now ready for press, has been produced jointly by Mr. Roys and France V. Scholes. It considers the history, ethnology, and linguistics of the Chontal Indians of the Acalan-Tixchel region in southwestern Campeche. The Chontal text, the only known existing document written in the Chontal language, will be reproduced in facsimile, for it is one of the most important sources for Maya history and ethnology that has been found in many years.

From the eighth volume of "Contributions to American Anthropology and History," the first paper (no. 40), *The archaeology of southwestern Campeche*, by E. Wyllys Andrews, was preprinted in February 1943. *Explorations in the Motagua valley* (no. 41), by A. L. Smith and A. V. Kidder, and *The astronomical tables of the Maya* (no. 42), by Maud W. Makemson, of Vassar College, are ready for final printing. The last report, Karl Ruppert's *The Mercado, Chichen Itza, Yucatan* (no. 43), is now being typed for offset. The whole volume will be distributed in the fall of 1943.

Mrs. Harrison has edited most of the manuscript submitted by Alfonso Villa R. on *The Maya of east central Quintana Roo*.

Tatiana Proskouriakoff is assembling her drawings for an album of Maya architecture and sculpture. The volume, to be ready for publication by the end of 1943, will contain a short introduction and 34 mechanically plotted perspective drawings rendered in black-and-white wash. Each plate is accompanied by a descriptive comment and a pen-and-ink sketch showing

the degree of certainty in the restoration. Sculptural details are represented in scratch drawings on Rossboard.

The collection of "Notes on Middle American Archaeology and Ethnology" has been increased by fifteen numbers during the year. The editor of the series, J. Eric S. Thompson, contributed six papers, Dr. Kidder three, and Dr. Halpern one, all listed in the bibliography at the end of this report. The remainder came from specialists outside the Institution: *A new pottery style from the Department of Piura, Peru* (no. 8), by John Howland Rowe, of the National University of Cuzco, Peru; *The payment of tribute in the Codex Mendoza* (no. 10) and *A note on Aztec chronology* (no. 11), by R. C. E. Long, of Portarlinton, Ireland; *A reconnaissance on Isla de Sacrificios, Veracruz, Mexico* (no. 14), by Wilfrido du Solier, of the National Institute of Anthropology and History, Mexico; and *Notes on sculpture and architecture at Tonala, Chiapas* (no. 21), by Linton Satterthwaite, Jr., of University Museum, Philadelphia. An index

will be issued when enough papers have been gathered to form a volume, but a list of contents is supplied from time to time while the volume is in progress.

Preparation of the typescript of volume II of the *Guide to materials for American history in the libraries and archives of Paris* (Publication 392) is finished. Of its 1080 pages, about half have been printed (by offset); the rest will follow within a few months. The compiler and editor, John J. Meng, has concluded work on the manuscript for volumes III and IV and is well advanced in that for volume V, the last. Volume I of the *Guide* (libraries) is separately indexed. This and the remaining volumes (archives) will be cumulatively indexed when publication is completed.

In addition to editing and seeing through press the afore-mentioned publications, Mrs. Harrison has advised members of the staff on details of presentation relative to the text and illustrations of their forthcoming reports, and has made minor researches connected with the preparation of their material.

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## SPECIAL PROJECTS: HISTORICAL RESEARCH

MARION E. BLAKE, Bradford, Vermont. *Preparation of a monograph on ancient Roman construction based on the material accumulated by the late Dr. Esther B. Van Deman.* (For previous reports see Year Books Nos. 38 to 41.)

Various demands due to war conditions have delayed somewhat the completion of the monograph dealing with ancient Roman construction. The work has advanced considerably, however, and the end is in sight. Chapter 1, "Introduction," has been written; chapter 2, "Materials," has been completely reorganized to eliminate references to buildings later than Augustus and shortened by cross references to later chapters. Chapters 3, "Stone walls," and 6, "Opus incertum, quasi-reticulatum, and reticulatum," have been expanded to give a general survey of these types of construction throughout Italy. Substantial progress has been made in eliminating repetition

in chapters 3, "Stone walls," and 5, "Arches and vaults," which deal with many of the same buildings. The enormous task of checking references throughout the entire study is well under way, and a bibliography of authorities and abbreviations has been started. An index of places has been compiled on cards, which will serve eventually as the basis of an analytical index designed to make the monograph a means of ready reference.

Only three tasks remain virtually untouched: the preface, the concluding chapter, and the illustrations, to which should perhaps be added the time-consuming task of retyping much of the manuscript.



## PALEONTOLOGY, EARLY MAN, AND HISTORICAL GEOLOGY

JOHN C. MERRIAM, President Emeritus, Carnegie Institution of Washington. (For previous reports see Year Books Nos. 20 to 41.)

The President Emeritus research report for 1943 is organized on the plan used for previous reports from 1938-1939 to 1942, but differs from them in that a greater percentage of the larger projects have been brought to the stage of final discussion, or have been so organized that the work may proceed satisfactorily under other auspices. The outstanding example of this type of treatment of materials appears in consideration of problems relating to studies on paleontological and geological history of the John Day region of eastern Oregon.

### RESEARCHES ON THE JOHN DAY REGION OF OREGON; WITH DISCUSSION OF PROGRAM TO MEET FUTURE NEEDS OF RESEARCH AND EDUCATIONAL ACTIVITIES

In previous reports, beginning with 1938-1939, there has been discussion of the extensive series of correlated researches directed toward attainment of an understanding of the story of geology and of the history of life in the John Day region of Oregon. The work of the writer devoted to interpretation of the John Day region began with an expedition into that area in 1899, and has been carried on continuously from that time until the present, both through field expeditions and through laboratory investigation. Beginning with an effort to learn something of the spectacular story of evolution of higher animals in that region, the studies were extended to include groups of lower animals without backbones, as also the flora, the general geology of the region, and certain aspects of petrography and mineralogy. In some of the later work, beginning investigation of the story of early man in America has

been included, so far as it is expressed in this region.

The group of investigators concerned with work in the John Day area has comprised representatives from many of the principal institutions of the west coast region, and a number of students from leading agencies concerned with geological and paleontological work in the eastern universities and museums. With development of cooperative work among the individuals and institutions represented, there exists an important complex of researches involving very many points of view, all of which are important individually, and especially significant when considered in relation to one another.

Results of the work of the writer in the John Day region are recorded in the *Published papers and addresses of John Campbell Merriam*, being volumes I to IV in Carnegie Institution Publication 500.

In the past year, specific attention has been given to the desirability of either bringing to conclusion certain phases of work relating to technical researches which can be taken up at any time, or planning such a program as will make it possible to carry these investigations forward through the medium of other students now at work, or who may desire to enter this field in the future.

It has been assumed that there is still, in the John Day region, a great wealth of material for studies of large advantage to science and to humanity broadly. Certain of the technical studies may perhaps be completed within a short time; others will interlock with investigations involving detailed work which should be carried on over extended periods. It is recognized

that, though it is often possible to continue a technical study indefinitely by accumulation of additional materials, and though such work has the definite value attaching to fundamental realities of science, it is also true that such material may be only the bricks by use of which major structures can be erected. On the other hand, since general or philosophical studies represent in large measure the conclusions toward which scientific studies are directed, there is presumably a responsibility resting upon the writer of this report to make an effort so to develop the values that are now evident as to open the way for the largest constructive use of the outstanding features in this region.

The major factors relating to the John Day program of the future may be considered under three heads:

1. The effort to safeguard continuance of research activities in the John Day region, through setting up of an informal organization to be known as John Day Associates.

2. Activities relating to use of features of the John Day region which may contribute materially toward education of the people of the state in thinking on major questions concerning the character and significance of natural phenomena, and which may also advance development of thought on the meaning of these phenomena in their relation to understanding of human problems in the future. Of particular importance in this plan is the preparation of clearly written publications relating to features of special human interest.

3. The setting up of a program by which the natural features of principal interest in the John Day region may be protected for their highest use in development of research and in education of the people, through establishing a series of reservations under the State Parks Office.

Commonly, research appears to move in cycles, which tend to correspond rather closely to the life periods of investigators concerned. But it is believed that advance in studies within the John Day region may go forward through a period of not less than one hundred years, and possibly reach much farther. The planning of an informal organization, to continue thinking in the fields of research for which favorable materials are found in the John Day region, is designed to promote continuity of effort and to make more effective the studies which may be undertaken. The invitation includes those who have already been concerned with these investigations and are most familiar with the subjects available for study. It is believed that the method, which has been approved by the Oregon State Board of Higher Education, will aid in development of research in many fields, and will facilitate synthesis of materials. It is hoped that the collective thinking of the group of investigators known as John Day Associates may not become so formal as to limit development of research in any of the directions in which work can be conducted to advantage.

The activities designed especially to advance education of the people are planned to aid in bringing about contact with the realities of nature in a manner tending to stimulate self-education. It is believed that this contact will promote initiation of thought on the part of visitors such as may lead to recognition of the power and movement illustrated in the natural world, the laws in accordance with which it develops, and the principle of unity which holds the features of nature together. It is hoped that contact with the phenomena of nature will lead to recognition of the fact that we live in a dependable, or law-controlled, universe in which advance or development is a normal mode of action.

It is assumed, also, that there will ulti-

mately be appreciation of the fact that what we know of history in the human group shows that basic principles dominant in development of other groups of organisms have had in general a corresponding influence in our own history. It is also considered possible that evidence of the extent to which so-called natural law has had an important place in early human historical development may lead to recognition of influence of these principles in peculiarly human relations, such as those involved in social and political problems in the present and future of mankind.

Preparation of a simple, carefully written book calling attention to the things of greatest interest in the John Day area would have large value in interpreting to the public the principal phases of reality which we consider important. It is possible that, in preparation for actual use or study of the area by visitors, a more technical publication in the nature of a guidebook might also be helpful.

Plans for safeguarding certain areas and features in the John Day region most important in providing materials for research, and opportunity for education, have been under consideration for a number of years, as noted in previous reports. Through the careful thinking of Samuel H. Boardman, Superintendent of State Parks, of Oregon, effort has been made to see how the things of greatest value could be protected and, at the same time, made available for research and educational use with a minimum of disturbance of what would be considered the natural activities for life in that region. The Highway Commission of the State of Oregon, the agency to which the state parks organization is responsible, has approached discussion of this subject in a sympathetic manner, and has proceeded in an orderly fashion to secure the data needed for carrying out such a program for state

park use as would fit into activities of these organizations.

*History and evolution of floras in John Day formations, Ralph W. Chaney.* Among the researches concerning history of life in the John Day region, one of the most consistently constructive is that of Dr. Ralph W. Chaney on the history of plant life in its relation to the geological story. The studies, carried on through many years, have contributed a great amount of information regarding types of plants in these formations, their variation, and their history through the formations in which they occur. The story of life as represented by plants has aided markedly in our interpretation of geological succession and correlation, and in forming opinion regarding changes of climate and other physical conditions which have taken place through the ages.

Dr. Chaney reports:

"Continuing study of Tertiary floras from the John Day Basin emphasizes their significance as guides to understanding of vegetation, both past and present. In no other part of the continent does the record so closely approximate completeness, for recurrent volcanism during much of the time provided ideal conditions for preservation of plant materials in fine-textured volcanic sediments, and flows of lava protected them from subsequent erosion. Varied climate and topography favored the development of rich and diversified vegetation, changing from epoch to epoch with a progressive trend toward wider extremes of temperature and lessening rainfall. From the subtropical rain forests of the Eocene and the temperate forests of the Oligocene and Miocene, there have been derived not only the hardy trees now scattered along the John Day valley, but many vegetation types spread widely over North America. The impact of changing topography and climate has brought new

plant populations to eastern Oregon, and has scattered the rich elements of its earlier forests widely across the continent.

"Current studies of the Mascall flora are tending to confirm our earlier opinion that the Upper Miocene forest of the John Day Basin was made up of floral elements now widely distributed over the northern hemisphere. In the Blue Mountains of Oregon and the Cascades to the west, there are a number of trees whose Miocene ancestors lived in the areas now rendered semiarid by their rain shadows. The present-day forest of valleys in the Coast Ranges of California contains redwood, alder, several species of oak, and numerous other modern equivalents of Mascall species. Southward in the highlands of Mexico and Guatemala, whence they appear to have migrated along the Cordillera in post-Miocene time, there are trees which show resemblances to Mascall species, mingled with others which appear to have had an origin in the south. As has been mentioned in previous reports, living forests of the Allegheny Plateau (Year Book No. 40, p. 183), in the lower drainage of the Ohio River (Year Book No. 41, p. 142), and elsewhere in the eastern United States include a large number of trees whose ancestry seems readily traceable to the Upper Miocene.

"In northeastern Asia, where the climate also is characterized by summer rainfall, there are many points of similarity with the composition of the Mascall flora. Our study of this Miocene forest involves analysis of living conditions in these widely separated areas, in an attempt to reach an approximate understanding of the climatic and topographic factors which controlled Tertiary vegetation, and which have been responsible for wide forest migrations in later geologic time."

*Significance of faunal zones represented by higher animals, Chester Stock and*

*Eustace L. Furlong.* Through a period of several years extensive studies have been made by Chester Stock and Eustace L. Furlong on the succession of life forms in the John Day region, especially in the John Day, the Mascall, and the Rattlesnake formation. The purpose of these investigations has been determination of the vertical or time range of different types of life, with a view to learning the extent to which genera and species have disappeared or have changed into other forms by some process of evolution. The fact that these sediments may include many hundreds of feet of strata, in which the lines of demarcation of layers or divisions are clearly marked, has suggested the possibility that careful collecting would show the vertical as well as the horizontal or geographic range of organic types.

Where careful collecting has been done on a series of well exposed formations by experienced collectors, it is not easy subsequently to increase the amount of material available unless new localities can be discovered, since the formations weather rather slowly and, up to the present time, few localities have been found at which fossils were sufficiently abundant to warrant digging or mining for specimens. Under the circumstances, it has been necessary to await the accumulation of materials over a considerable period before attempting to draw final conclusions as to the meaning of distribution as determined by field work.

In order to bring together at this time as clear a statement as possible of the materials available for study on vertical distribution of organic types in the John Day section, Dr. Stock and Mr. Furlong have carried out a review of the available materials as a matter of record. Mr. Furlong examined especially the collections at the University of California, where the materials accumulated in the first studies of

this subject were deposited. He has compiled a list of sixty-nine collecting localities of the University of California Museum and thirty-five localities of the California Institute of Technology, together with names of the genera and species that have thus far been recovered. It is to be assumed that, with time, other collectors and other institutions will work over the region which has been studied by the University of California, California Institute, and the University of Oregon, so that the number of genera and species represented in these sections will be enlarged. The advance of knowledge in this particular subject has great importance for general studies on evolution of organic types, as, also, for interpretation of geological sequences and for correlation of deposits in regions so sharply or widely separated that continuity of strata through mapping is not possible.

*Studies on the history and evolution of lower animals in formations of the John Day area, E. L. Packard.* The work of Dr. E. L. Packard concerning the history of lower animals without backbones has contributed important data bearing on problems of geological interpretation, on questions touching changes of physical conditions or environment, and on steps in evolution of lower animals which have gone forward approximately parallel with those of higher animals and of plants.

Dr. Packard has now in process of final organization manuscripts recording results of his work in recent years. The following notes present certain details relating to the work which he has under way:

"During the past year the Cretaceous invertebrate faunas from the Mitchell beds of upper Horsetown age in the John Day area have been checked again, and the descriptions rewritten. Over fifty species of ammonites are recognized, among which are a number of new forms. The ammonite fauna has definite affinities with the

upper Horsetown of California and includes species ranging more widely within the Indio-Pacific province.

"This fauna, which is confined to the lower shale member of the Mitchell beds (for which the term Mitchell formation will later be proposed), also includes a limited pelecypod and gastropod fauna, the former characterized by species of *Trigonia* and *Pholadomya*.

"The Mitchell beds also include three other distinctive stratigraphic members, two being massive conglomerates separated by a shale, not unlike the lower or 'Meyers' shale member. These three uppermost members have not yielded fossils, although extensive search has been made for them.

"The conglomerate members are not distinguishable from the barren conglomerates outcropping along the John Day River at the base of the John Day formation below Picture Gorge.

"Somewhat similar conglomerates occur at Antone, but they contain, as do the associated sandstones and shales, a distinctive Upper Cretaceous fauna, comprising well known gastropods and pelecypods. That fauna occurs in restricted areas along the northern face of the Ochoco fault scarp as far east as South Fork of John Day, and along Beaver Creek on the southern slope of the Ochoco structural block."

*Studies on general geology of the John Day region, John P. Buwalda.* Circumstances incident to the war situation have delayed publication of extensive reports on the geology of the John Day country which have been worked out with great care and fine vision by Dr. Buwalda. It is clearly desirable to take such a course as will lead to the best possible presentation of these results, rather than to allow, through hasty publication, the possibility of omissions which could be covered adequately later only by more or less frag-

mentary publications. Though continuous field researches are impossible at this time, cooperative thinking on the problems represented has been carried on with other students.

*Problem of early man in the John Day region.* The present world-wide disturbance has eliminated a large part of all research concerning fundamental problems relating to evolution of man over the earth. With conclusion of the present world war, however, some of the most important problems to be faced will concern interpretation of relations among nations, for understanding of which it is important to have a knowledge of the evolutionary development and relationships of human groups.

Researches on the history of early man, carried out by Dr. L. S. Cressman of the University of Oregon in recent years, have made valuable contribution to our knowledge of this subject. Especially significant is his paper on *Archaeological researches in the northern Great Basin*, recently published by the Carnegie Institution of Washington. As this paper deals with important occurrences of remains in south-central Oregon, there is inevitably inquiry as to whether the region of special interest contributing data relating to early man in Oregon might be expected to include at least some part of the John Day area. Up to the present time little attention has been given to this possibility, but Dr. Cressman has carried out reconnaissance studies which gave very favorable results and is of the opinion that the John Day region might furnish materials of interest and importance.

#### DEVELOPMENT OF RESEARCH ON THE DEPOSITS OF FOSSIL REMAINS AT RANCHO LA BREA

During the past year Dr. Chester Stock has given continued attention to further

development of the great opportunity for studies in the history of life afforded by collections obtained at Rancho La Brea in Los Angeles. These researches have included consideration of classification and organization of the splendid collections at the Los Angeles County Museum. One of the most important advances has involved development of the collection of mounted skeletons of Pleistocene birds from the asphalt deposits. These mountings show particularly well the size and proportions of some of the most striking raptorial birds, as well as of the extinct stork and wild turkey. Never before have so many extinct birds been made available in mounted form; thereby it is possible to increase the knowledge of these creatures beyond the details of morphology acquired through study of individual parts of the skeleton. The success of this type of preparation is due largely to the painstaking efforts of the museum preparator, Eugene J. Fischer. The materials for the mounted specimens were selected from the large collection by Dr. Hildegard Howard. It is hoped that it may be possible to prepare a restoration of the large condor-like vulture (*Teratornis merriami*).

Mr. Fischer has also just completed an excellent mounted specimen of the extinct bison (*Bison antiquus*) from Rancho La Brea. This represents one of the largest individuals of the Bovidae to be recorded from the asphalt. A paper describing this specimen is now being prepared by Dr. Stock.

#### RESEARCHES ON ANIMALS CONTRIBUTING ESPECIALLY IMPORTANT DATA BEARING UPON THE SIGNIFICANCE OF EVOLUTION

Through all the reports which have been published on this series of paleontological and historical researches there has been emphasis upon significance of certain

phases of the paleontological record which have made particularly important contribution toward understanding the mode of operation of evolution. Attention has been called especially to work done upon a few groups in which evidences of evolution not only are strongly marked, but have been interpreted more easily than is true in certain other divisions of the organic world. In the study of two widely different groups of higher animals, data relating to history and development have been accumulated which seem to have exceptional interest and importance. One of these phases of work involves the study by Dr. Remington Kellogg, of the U. S. National Museum, on evolution or specialization of the members of the whale group. The other series of studies is that by Mr. Eustace L. Furlong, of the California Institute of Technology, on the history of certain groups of antelopes. The fact that both the whales and the antelopes are known as highly specialized animals has relation to the kind of evidence of evolution furnished. Whatever significance there be in other important aspects of the story of life, there can be no doubt that scientific interest stresses the evidence of continued changes through the ages by means of which more highly specialized and, in some cases, more highly effective types of life come into being.

The work of Dr. Kellogg on the whales presents one of the most spectacular series of changes that we know in the whole range of history of organisms. The fact that these changes have led toward the development of animals specialized for aquatic life does not mean that the result of the changes is less important than would be the case if they were leading toward very high development of a brain system or of intelligence. A point of great significance is that the series of steps moves rapidly and quite directly toward the de-

velopment of characters which have importance for life in this particular group, and that there is much information bearing upon the whole problem of method and ultimate result of evolution which must be studied if we are to learn the real nature of this process, and also ultimately to know whether changes of this sort may be induced through influence of human intelligence.

The work of Mr. Furlong on the antelopes deals with a type of life in which the specialization is totally different from that in the whales, and in which it is perhaps true that the aspects of specialization are more sharply localized in the body. At the same time, one must recognize that there is a high degree of correlation among the various aspects of the specialization.

#### INVESTIGATION OF MAJOR PROBLEMS IN GEOLOGY AND PALEONTOLOGY OF THE GRAND CANYON

In planning a program of interpretation covering major features of the Grand Canyon National Park some years ago, effort was made to select those questions which seemed of exceptional importance, and regarding which relatively little had been known. Investigation of certain of these problems was carried out in considerable part by Edwin D. McKee, then naturalist at the Grand Canyon on the staff of the National Park Service. Not only has the material obtained in his studies contributed much toward understanding the broader outlines of history in this area, but, in general, it has appeared that the investigation of each of these problems has related itself in some measure to work on other subjects, so that his researches have presented a connected story of great importance in interpretation of major values at the Grand Canyon.

One phase of Mr. McKee's work having exceptional interest involves studies made

on conditions and forces now operating, with a view to interpreting major phenomena represented in geological history of the Grand Canyon region. For example, to attain understanding of certain aspects of what appeared to be a delta formation, he made studies on the delta of the Colorado River; these have thrown light on the Grand Canyon formation, giving additional evidence of its vast antiquity.

A further illustration of this method is found in recent studies by Mr. McKee at the Museum of Northern Arizona, regarding the formation of sand dunes. He has been able, by use of wind tunnels and a fan, to reproduce types of sand dunes, including the minor structures which seem to be represented in the geological formations. By comparing these results with study of the Coconino formation in the Grand Canyon, it has been possible to explain many features that have heretofore been very puzzling. More than this, Mr. McKee has been making studies on various types of lizard footprints found in the dune sand in the Grand Canyon formations.

A monograph on the Grand Canyon Cambrian, by Mr. McKee and Charles E. Resser, of the U. S. National Museum, has been approved for publication by the Carnegie Institution of Washington.

#### EXPRESSION OF NATURAL LAW AS FOUNDATION OF BELIEF

Assuming that objectives of President Emeritus research may have largest importance in those phases of study involving attainment of conclusions relating to fundamental ideas, it is natural that through this period of work there has been continuous interest in contributions of science having special significance in consideration of human problems. With accumulation of data bearing upon this subject, it has seemed increasingly clear

that great importance attaches to effort directed toward study of methods and conclusions of science which contribute toward understanding the rapidly growing number of complicated problems that have to do with world questions.

Recent publication of a book on the influence of nature in human experience has emphasized certain aspects of natural law the interpretation of which has had important place in the thought of the writer. These ideas have been expressed to some extent in all the President Emeritus research reports up to the present time. So, in the report of 1938-1939 attention was called to the importance of examining evidence suggesting that contributions of science may come to have large value in formulation of a philosophy with wide-reaching implications for human life. At that time there was suggested for consideration the possibility that a philosophy based upon expression of natural law might furnish principles of value in a restatement of religion or ethics, such as would be acceptable to a large percentage of thinking people. It was also noted that re-study of materials available might indicate that possibly the greatest contribution of science concerns its influence in determining our attitudes of mind and our aspirations. Reference was also made to the idea that materials of research which have been tested sufficiently to establish their reality furnish exceptionally valuable foundations for the building of human beliefs, and that, to the extent to which science demands a basis of reality for what is used in development of ideas, its methods may properly serve as pattern in study of specifically human problems.

An interesting aspect of the relation between study of nature and development in beliefs presents itself in the possible influence of certain points of view upon the relation between science and philosophic or re-



ligious beliefs. If it be demonstrated that with increasing knowledge of the nature of the world about us we may develop better-founded and humanly more clearly adequate ideas regarding fundamental beliefs, then there would be reason for pressing our fundamental study of nature by more intensive scientific research. So, it may appear that, although for a considerable period science was assumed to exert a destructive influence upon religious and other fundamental beliefs, the real situation would be one in which the highest advance of science would be recognized as contributing toward improvement of our point of view or of our beliefs. There would thus be attained a stage at which the advance of science, philosophy, and fundamental beliefs would be closely linked, and so intimately related that they should go forward as one great movement.

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